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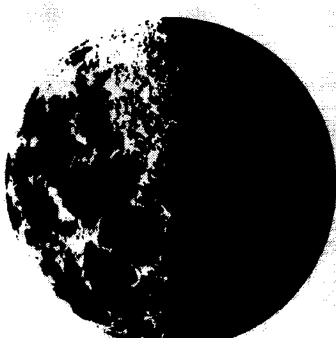
QUARTERLY RELIABILITY STATUS REPORT
NAS9-150
(U)

31 July 1965



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QUARTERLY RELIABILITY STATUS REPORT
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Exhibit "I", Paragraph 7.3

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SPACE and INFORMATION SYSTEMS DIVISION

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FOREWORD

The information contained in this report was prepared by Apollo Reliability to provide status on Reliability activities for the period 10 March 1965 to 10 June 1965. In the interest of program cognizance, the first section has been organized according to the eleven contractual Reliability tasks.

NORTH AMERICAN AVIATION, INC. SPACE and INFORMATION SYSTEMS DIVISION

TECHNICAL REPORT INDEX/ABSTRACT

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ABSTRACT

The document summarizes the efforts of Apollo Reliability during the quarter 15 March to 15 June 1965. Departmental support for Apollo end items, reliability tasks, and special programs is described. Detailed reliability information is included for each spacecraft subsystem and for ground support equipment.

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1.0 TASK IMPLEMENTATION

1.1 PROGRAM MANAGEMENT

1.1.1 FLIGHT VEHICLE SUPPORT

The scheduled task milestones in support of flight vehicles are shown in Figure 1-1 for spacecraft subsystems and in Figure 1-2 for ground support subsystems.

1.1.1.1 Boilerplate 22

The main effort on Boilerplate 22 during this period was associated with preflight-test checkout evaluation and preparation of the reliability flight readiness report. Checkout of the vehicle at Downey was completed on 12 March 1965. No major problems, other than the damaging of the two earth landing system sequencers because of improper test techniques, were encountered. The damaged units were replaced following a satisfactory vehicle wiring check. Initial field buildup was initiated during March and was continued until launch on 19 May 1965.

In conjunction with field site checkout, minimum airworthiness testing of the Boilerplate 22 type of systems was performed at Downey. In general, all testing demonstrated equipment operational capability in the expected mission environments. One exception, the power distribution box, was determined to be inadequate for flight usage. Circuit breakers used in this box exhibited a sensitivity to vibration that resulted in accidental or unintentional operation. As a result of testing, all active circuit breakers in Boilerplate 22 were hard-wired before launch.

The Boilerplate 22 reliability flight readiness reports were issued on 26 April (preliminary) and 10 May (final) to support the preliminary and the final flight readiness reviews on May 4 and 14, respectively. All Boilerplate 22 systems were considered acceptable for flight and a high probability of mission completion was predicted.

Boilerplate 22 was launched at 0601 MST on 19 May 1965. The final countdown was normal, all systems indicating a go status. Following a normal lift-off, the LJ-II boost vehicle began a slow roll at approximately T+5 seconds. The roll rate continued to increase until approximately T+25 seconds, at which time the boost vehicle began to break up. This breakup

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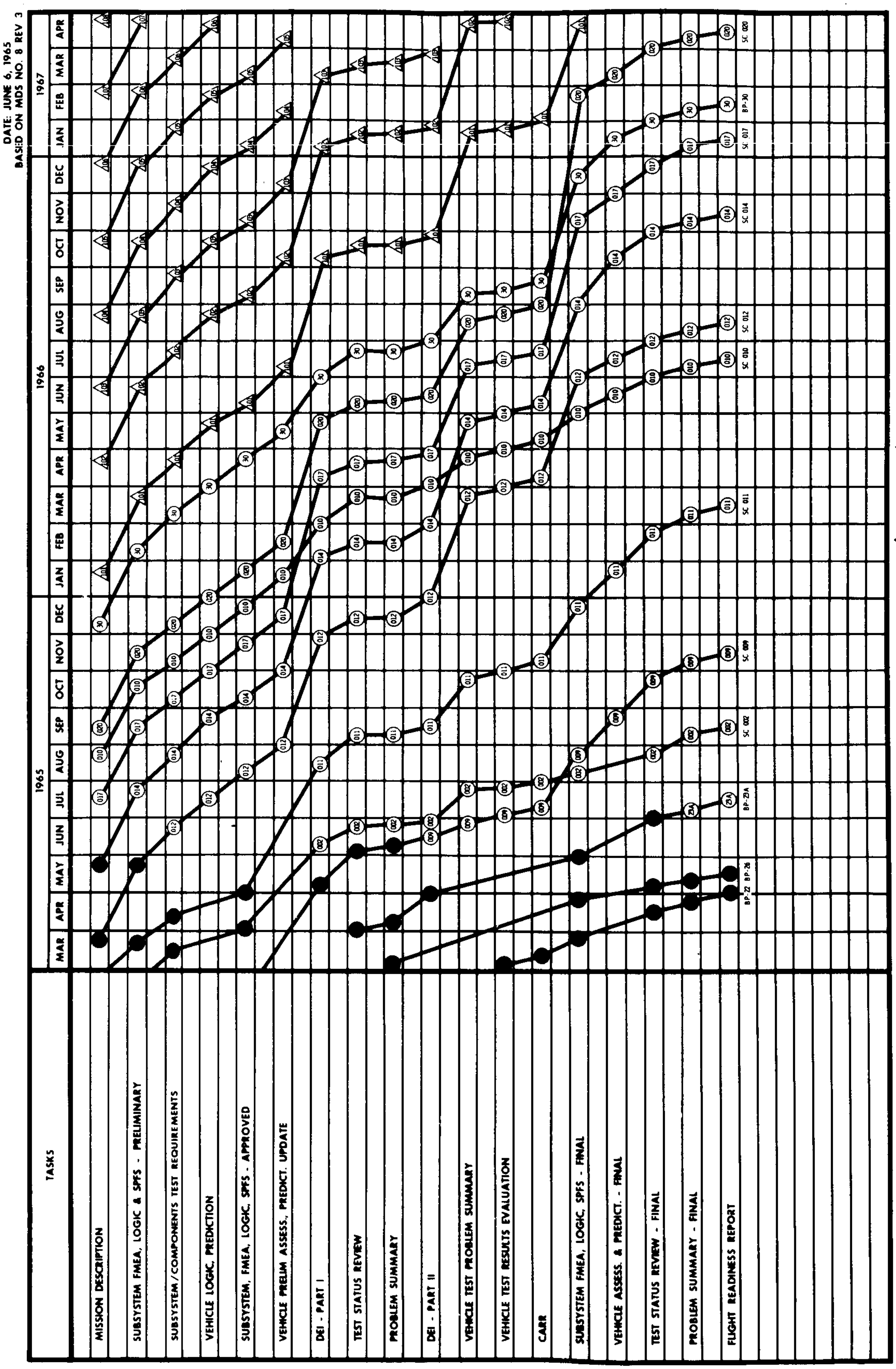

Figure 1-1. Reliability Support Schedule for Flight Vehicles

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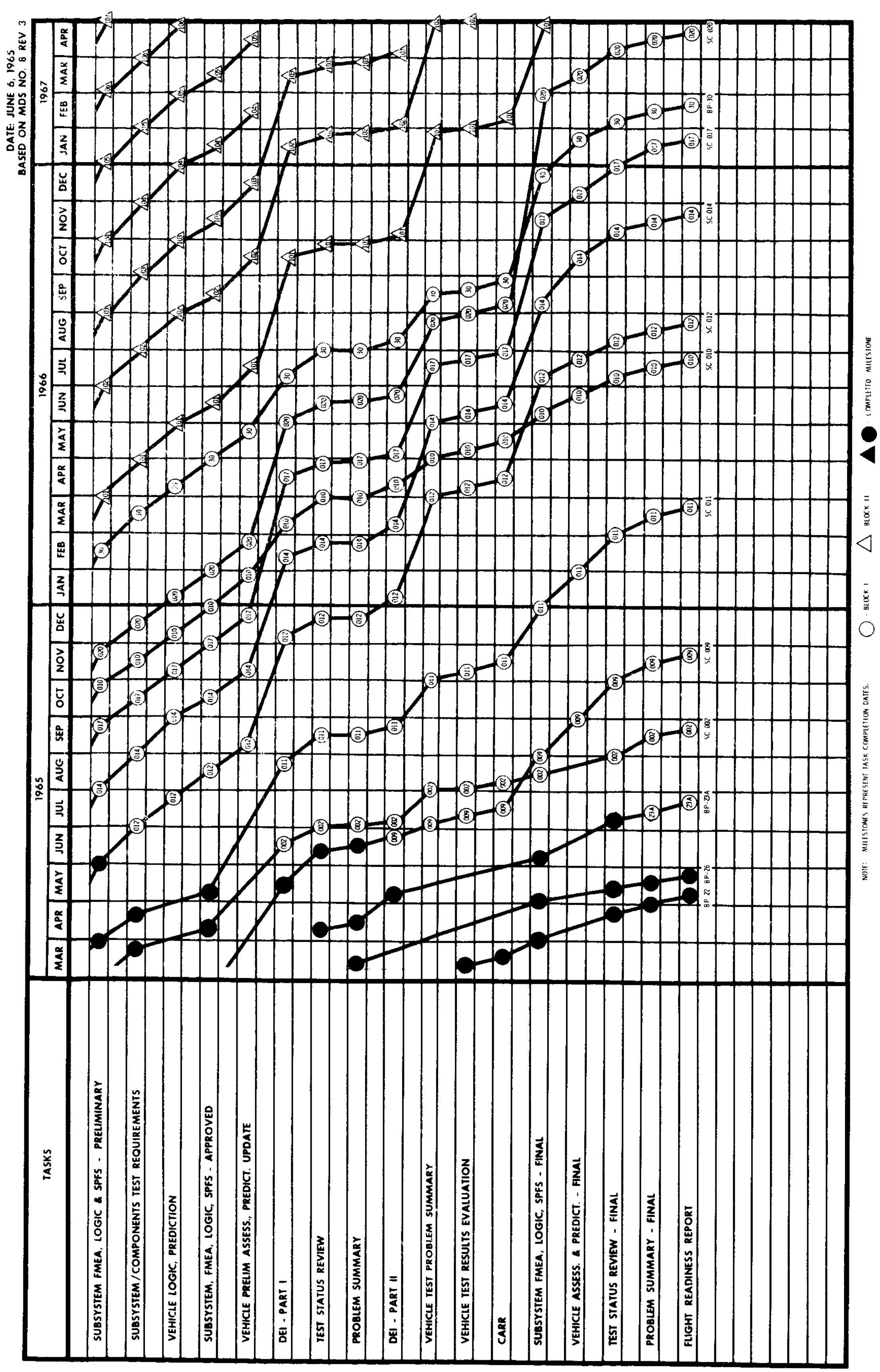

Figure 1-2. Reliability Support Schedule Associated With Flight Vehicles Ground Support Subsystems

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initiated an LEV abort at approximately 19,000 feet MSL. All LEV systems functioned successfully, and the command module was recovered without damage.

Postflight evaluation of recorded data and inspection of hardware indicated only one significant abnormality: two reefing line cutters on one drogue chute failed to fire. The two failed units are to undergo failure analysis at Northrop-Ventura. Results of this analysis and the corrective action required will be covered in subsequent reports. Final postflight evaluation is in progress, completion being scheduled for 18 June 1965.

1.1.1.2 Boilerplate 23A

As the result of a development engineering inspection (DEI) conducted at WSMR on 1 May 1965, five request for changes (RFC's) were written. Four required minor modifications and justifying information for fit of the boost protective cover; the other required the removal and/or fairing of sharp edges—a potential hazard to parachute deployment—on the top deck. All RFC's were fulfilled in this reporting period.

Earth landing subsystem reefing line cutters have a discrepancy record because of failures that occurred during the Boilerplate 22 flight. With the probability of the failure of individual reefing cutters (determined from two boilerplate drop tests and the Boilerplate 22 flight) as a basis, the use of the cutters currently installed in Boilerplate 23A will be recommended. Although some risk may be entailed in the possible non-disreefing of a drogue chute, sufficient redundancy is present to assure the achievement of mission objectives.

Drogue chute cutter R = 0.8333
Main chute cutter R = 0.9815
Probability of loss of one drogue chute due to cutter failure = 0.1036
Probability of loss of both drogue chutes due to cutter failure = 0.003
Probability of loss of one main chute due to cutter failure = 0.000036

1.1.1.3 Boilerplate 26

Boilerplate 26 was successfully launched into orbit atop Saturn Vehicle SA-8 on 25 May 1965. Tower-jettison occurred as planned and the Pegasus satellite was subsequently deployed. As a result of the temporary loss of data from 3 of the 12 RCS thermocouples during boost (all dropouts were observed during the transonic high vibration boost phase), improved welding methods are being employed in the buildup of the SM RCS quad for Boilerplate 9A.

In preparation for the mission, reliability support consisted of review and the approval of tests on airborne equipment, assurance of reliability in design, and follow-up on all failures and unsatisfactory conditions. The previously issued reliability flight readiness report for Boilerplates 16 and 26. was updated to reflect configuration changes and problems experienced subsequent to its issuance in January. The most significant of these were the following:

1. The reliability of the tower separation single-mode bolt was increased with the addition of 25 percent more powder.
2. An instrumented RCS quad was added to the service module to provide better data on boost heating than was previously obtained on the Boilerplate 15 flight. A more reliable installation was obtained by welding improved thermocouples directly onto the RCS nozzle extensions.
3. The reliability of the pyrotechnic batteries was increased by the substitution of an improved design that had successfully passed the NASA-type-qualification tests at MSC.

The updated reliability flight readiness report was distributed internally, and approval for launch was recommended to program management.

1.1.1.4 Boilerplate 30

Reliability inputs were provided to the Boilerplate 30 end-item specification, SID 64-1083. Boilerplate 30, replacing Spacecraft 015, was redefined during this reporting period. Its mission is an unmanned checkout of the LEM in earth orbit.

1.1.1.5 Spacecraft 009

Support activity was provided for the Spacecraft 009 development engineering inspection (DEI), Parts I and II. Single-point failure summaries were submitted for the Part I design review and summaries of open problem reports and commercial part applications were provided for Part II, a hardware review. During Part II of the DEI, the NASA/GE reliability section conducted an informal review of the Spacecraft 009 reliability effort which resulted in seven RFC's. Of the seven, four were accepted, one was approved for study, and two were rejected.

Action items assigned to Reliability and subsequently completed during the report period were to:

1. Reflect certification test network (CTN) part numbers in all failure reports
2. Provide a listing of all Spacecraft 009 open failure reports
3. Provide a listing of Spacecraft 009 parts that are not high reliability parts

The Cannon connectors, MC 414-0365, used in multiple applications on Spacecraft 009, present two problems. The ME 414-0102-0018 connector (shell size 8) reflects a weakness in the wave spring that permits the internal portion of the connector to cant in the connector body. Although it has not resulted in a failure, this condition prompted an unsatisfactory condition report. The ME 414-0106-0006 and ME 414-0119-0020 connectors (shell size 10 and 12) reflect another condition: the retaining ring slips out of position and causes the connector to fall apart. Since all the failures occurred subsequent to qualification of the MC 414-0365 connectors, Apollo Reliability initiated a study to resolve this problem. The qualification test report was examined and revealed no previous problems of this nature. Since the connectors on Spacecraft 009 have not been subjected to 100-percent cycling inspection at the vendor, they are being cycled ten times to reveal any inherent defects. The connectors are being subjected to a critical vibration test beyond the levels anticipated for the LOR mission.

The shell size 8 connectors, also, will be included in the vibration test. It is anticipated that the wave spring problem on the shell size 8 connector will be resolved on Spacecraft 009 by the addition of a safety wire through the engaging slot to prevent disengagement.

Another major problem in the completion of Spacecraft 009 is the contamination generated within the RCS helium panel. This situation was aggravated by the delivery of units from the suppliers with contaminants and by the brazing operations at S&ID. A study is being made at S&ID to resolve all the problems associated with this hardware.

1.1.1.6 <u>Spacecraft 011</u>

At the Chief Engineer's review of known and potential problem areas on Spacecraft 011, Reliability presented nine specific items in need of design improvements which are now being investigated. Reliability was assigned the action of closing out a number of failure reports generated during qualification testing.

A reliability survey was conducted on the usage of commercial parts on Spacecraft 011. Although the schedule dictated the acquisition of a number of electrical and electronic parts from commercial sources, the survey revealed that only controlled or high reliability parts are being used in critical applications.

1.1.1.7 <u>Spacecraft 012</u>

A preliminary mission spacecraft compatibility evaluation (PMSCE) based on the Block I basepoint mission was supported; the reliability activity was integrated with the total PMSCE report. The results of the PMSCE are being coordinated with NASA for further Spacecraft 012 mission planning and refinement.

Efforts were supported to incorporate high-reliability and controlled electronic and electrical parts into the Spacecraft 012 vehicle. The task is considered to be progressing satisfactorily for S&ID-supplied equipment. Greater effort is now being devoted to critical equipment furnished by subcontractors and suppliers.

A briefing on potential single-point failures of Spacecraft 012 is being prepared for presentation to engineering management to resolve those potential single-point failures which would have the most impact on the mission or have a high probability index.

1.1.2 GROUND VEHICLE SUPPORT

1.1.2.1 Boilerplate 14

The principal tests completed in the Phase III - Spacecraft 009 Block I support of the Boilerplate 14 test program were the integrated test No. 2 and the Spacecraft 009 mission simulation. The fuel cell tests are now in progress. The guidance and navigation tests, the CM-SM separation test, and the Spacecraft 009 general support test will follow the fuel cell test and complete the Phase III program. The test setup is shown in Figure 1-3.

The main objective of the integrated test No. 2 was to verify the operational compatibility of the sequential events control system (SECS) when interfaced with Boilerplate 14 systems and acceptance checkout equipment (ACE). The Boilerplate 14 configuration at the time of the test consisted of mated boilerplate command and service modules stacked on a boilerplate adapter. The standard facility, ACE and GSE configuration, was utilized. The following subsystems had been installed and were operating: reaction control, service propulsion, stabilization and control, environmental control, communication, instrumentation, and electrical power.

The sequential events control subsystem (SECS) included a prototype master events sequence controller, a service module jettison controller, a command module reaction control subsystem controller, and an earth landing subsystem controller. A summary of the specific test objectives and results is shown below:

1. Verification of the operational compatibility of the Boilerplate 14 SECS with ACE. This objective was only partially accomplished. Difficulties related to the inacessible addresses in the digital test command system (DTCS) were encountered but were overcome on the spot. Frequent loss of PCM synchronization and erroneous downlink addresses resulted in some loss of data.

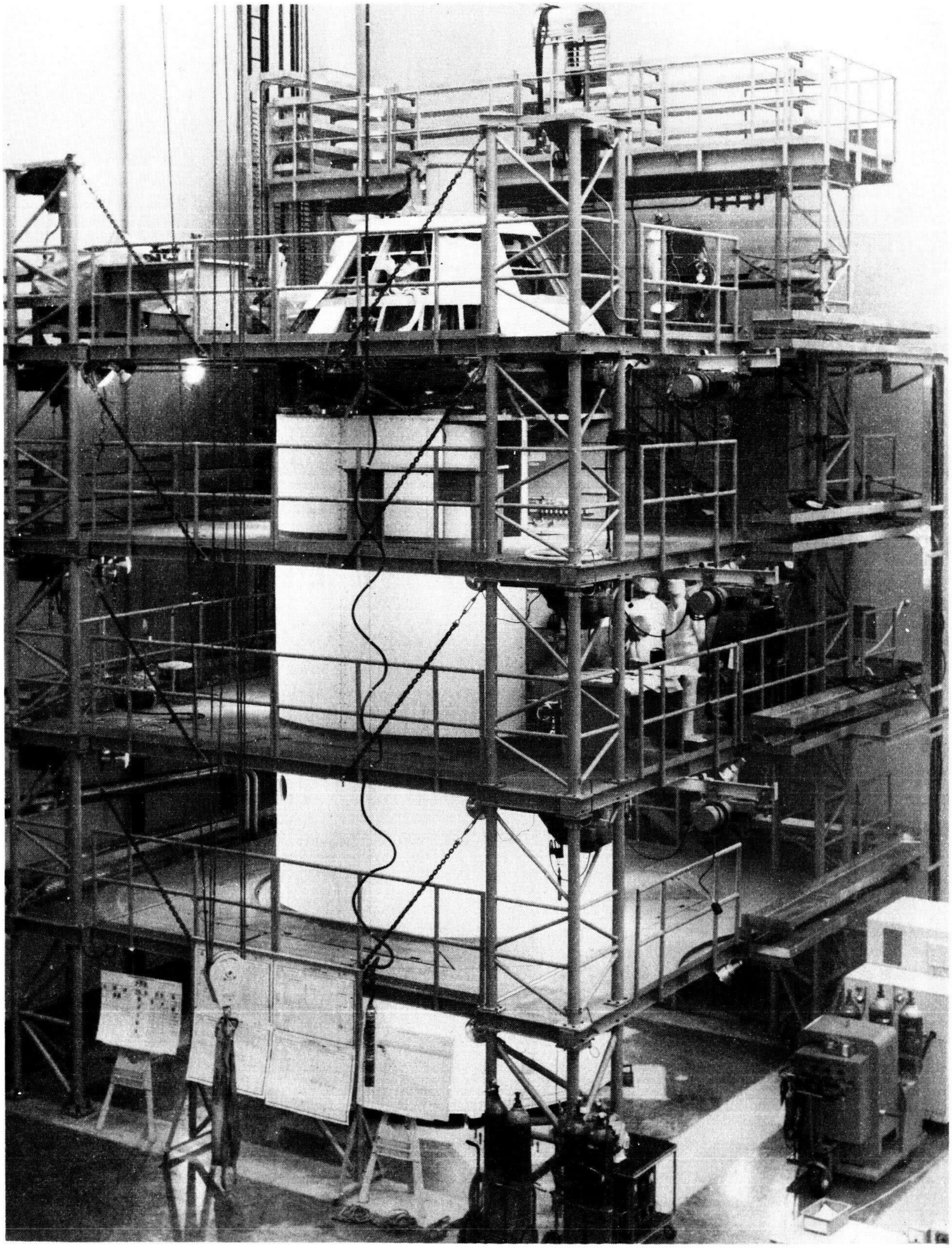

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Figure 1-3. House Spacecraft Test Installation

2. Verification of the operational capabilities of the Boilerplate 14 SECS with other spacecraft systems. This test objective was realized. Compatibility between SECS and Panel No. 3 could not be verified because of a shorted condition in this panel requiring its removal from the vehicle.

3. Verification of the operational compatibility of the Boilerplate 14 SECS with other auxiliary and servicing equipment. This test objective was accomplished. The C14-451 barometric console was not utilized in this test. Thus its compatibility was not verified; however, it will be scheduled during the Boilerplate 14 Spacecraft 009 mission simulation.

4. Verification of the compatibility of ACE digital to analog converters (DAC) with the stabilization and control system (SCS) attitude gyro. This objective was accomplished. Comparisons of the various methods for torquing the SCS attitude gyros were made; the most accurate means of torquing was identified.

The conclusions arrived at from this test are summarized as follows:

1. SECS Checkout: The SECS was successfully checked out during a simulated LES pad abort mode, LES attitude abort mode, and CM-SM separation.

2. Subsystem Checkout: All subsystems were checked out functionally and proved to be correctly installed, except the illumination subsystem and timer reset function. These items are not included in Boilerplate 14.

3. ACE: With the exception of some loss of synchronization, all ACE difficulties after detection were corrected. Wiring and connector problems encountered with ACE carry-on equipment were identified.

4. Gyro Torquing: The conclusion arrived at was that a hardware change was a proper means of resolving incompatibility between ACE, DAC, and the attitude gyros. The most accurate gyro torquing subroutine was determined. A procedural error in the control and display switching configuration was detected and corrected.

The reliability milestone and support schedule for Boilerplate 14 is shown in Figure 1-4.

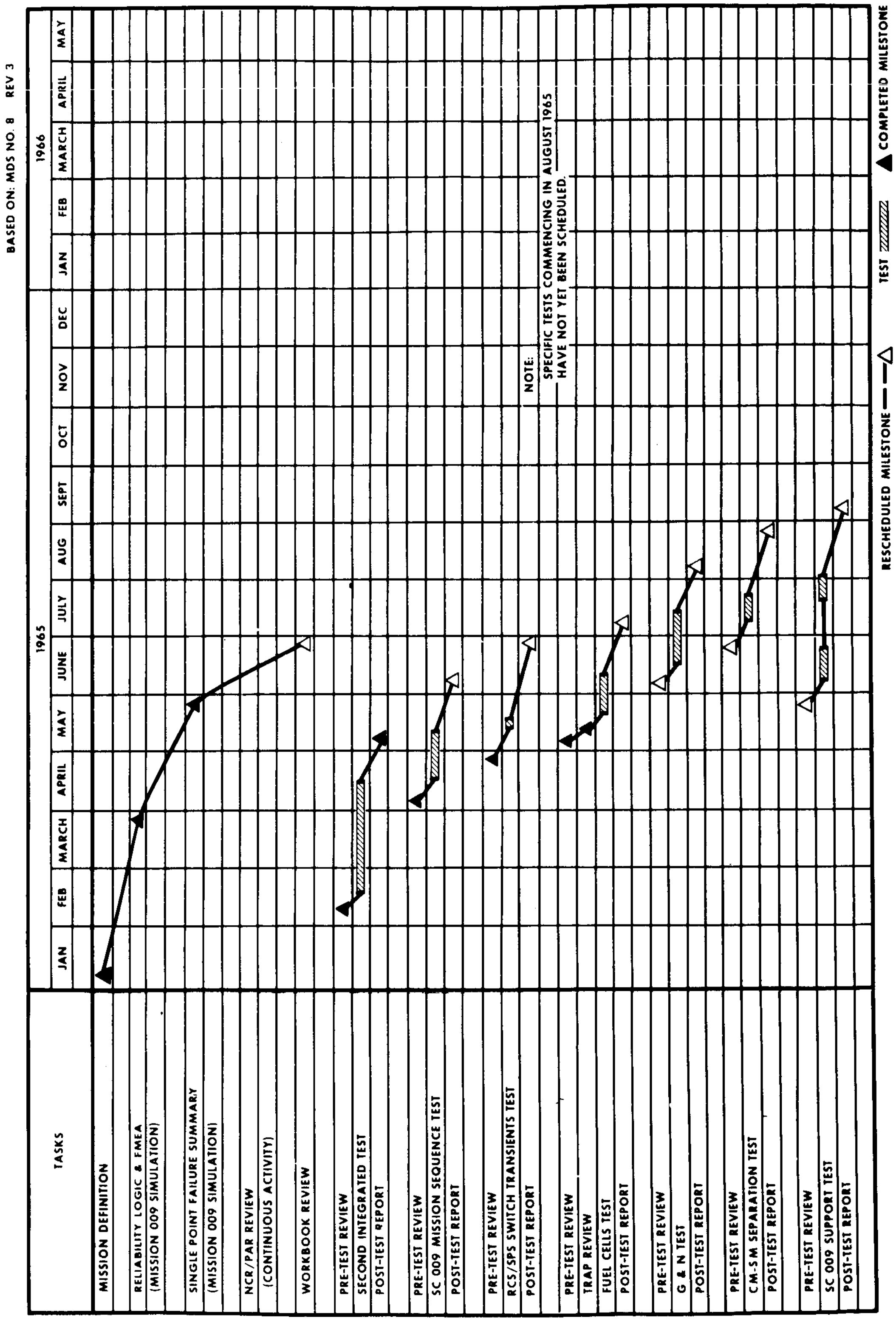


Figure 1-4. Reliability Support Schedule for Boilerplate 14

1.1.2.2 Boilerplate 28

The reliability support schedule for Boilerplate 28 is presented in Figure 1-5. The schedule was revised to reflect the most recent proposed test dates.

No impact tests were conducted during this reporting period. Detail components simulating the spacecraft configuration are being installed within the toroidal section of the command module in preparation for the next series of water impact tests.

Block I and Block II master end-item specifications were revised by specification change notice (SCN) to reflect the use of the reliability objective in conjunction with a statistical landing condition model to establish the design criteria for vehicle structural performance at impact and during postlanding. The SCN's reflect also the reliability reapportionment discussed in the previous issue of this report (SID 62-557-13). The SCN's were submitted to NASA by NAA letter 65MA3209 dated 27 April 1965, which also summarizes the history and present status of the command module water impact capability development program and the Boilerplate 28 test program.

The probability of land impact is being determined for use in establishing the crew support subsystem design criteria and the Boilerplate 28 and Spacecraft 002A land-impact test criteria.

The next series of Boilerplate 28 water impact tests is presently scheduled for July 1965. The tests are designed to investigate the effects of maximum side- and aft-loading on the toroidal section of the aft heat shield, and constrain the Block I flight spacecraft.

1.1.2.3 Spacecraft 001

The first firing test series at the Propulsion System Development Facility (PSDF) was completed satisfactorily with a total of 765 seconds of engine time. During down time following the test series, the spacecraft was updated to include gimbal actuators, baffled injector, and a new engine. Series II tests will include gimbal operations and an evaluation of the use of a single regulator and a baffled injector.

An evaluation is being prepared for the Spacecraft 009 support test series as detailed in the task and schedules of Figure 1-6. In addition to these tasks, the Spacecraft 001 configuration status and test program are being compared with the Spacecraft 009 certification test network (CTN) requirements to insure conformance.

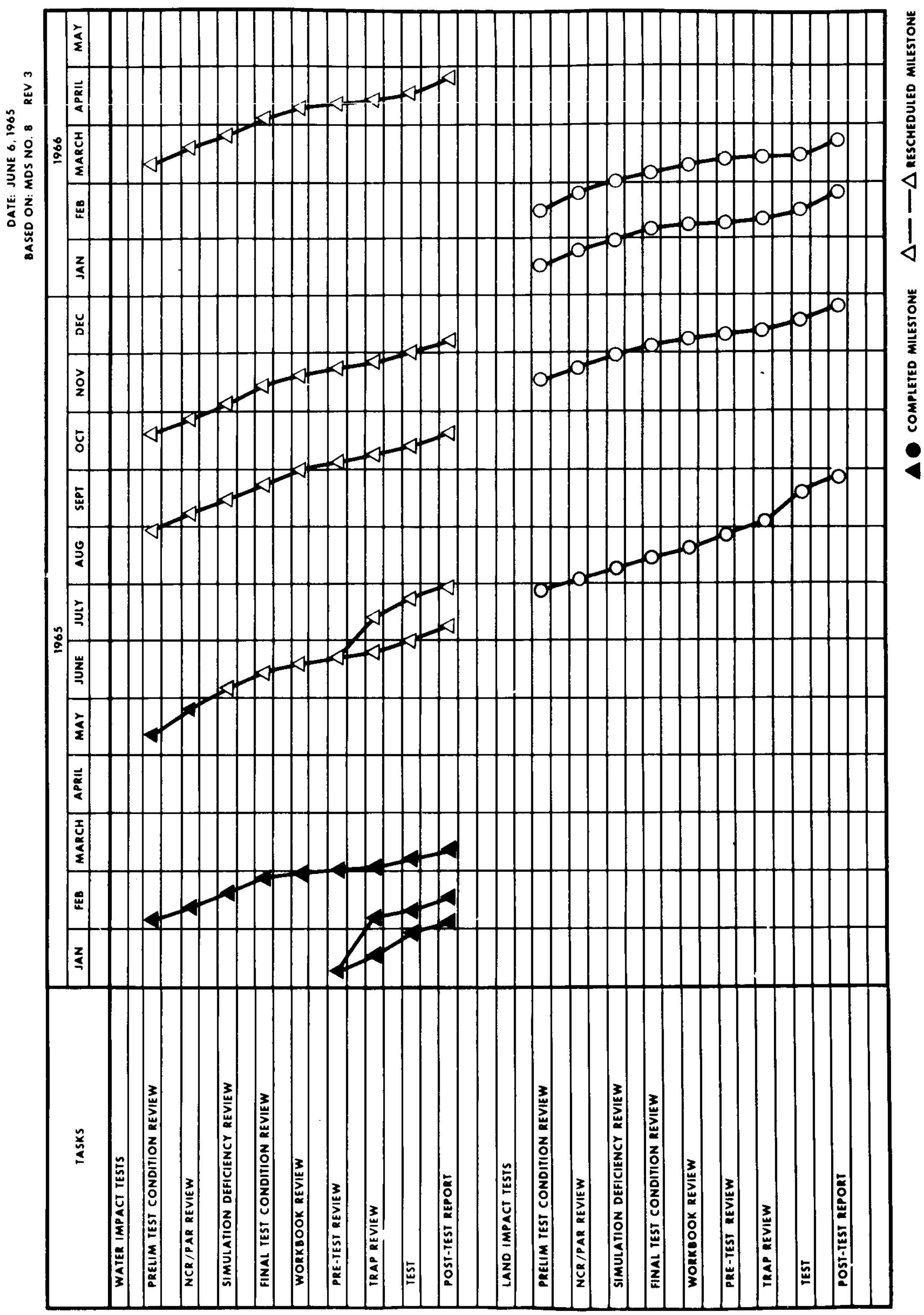


Figure 1-5. Reliability Support Schedule for Boilerplate 28

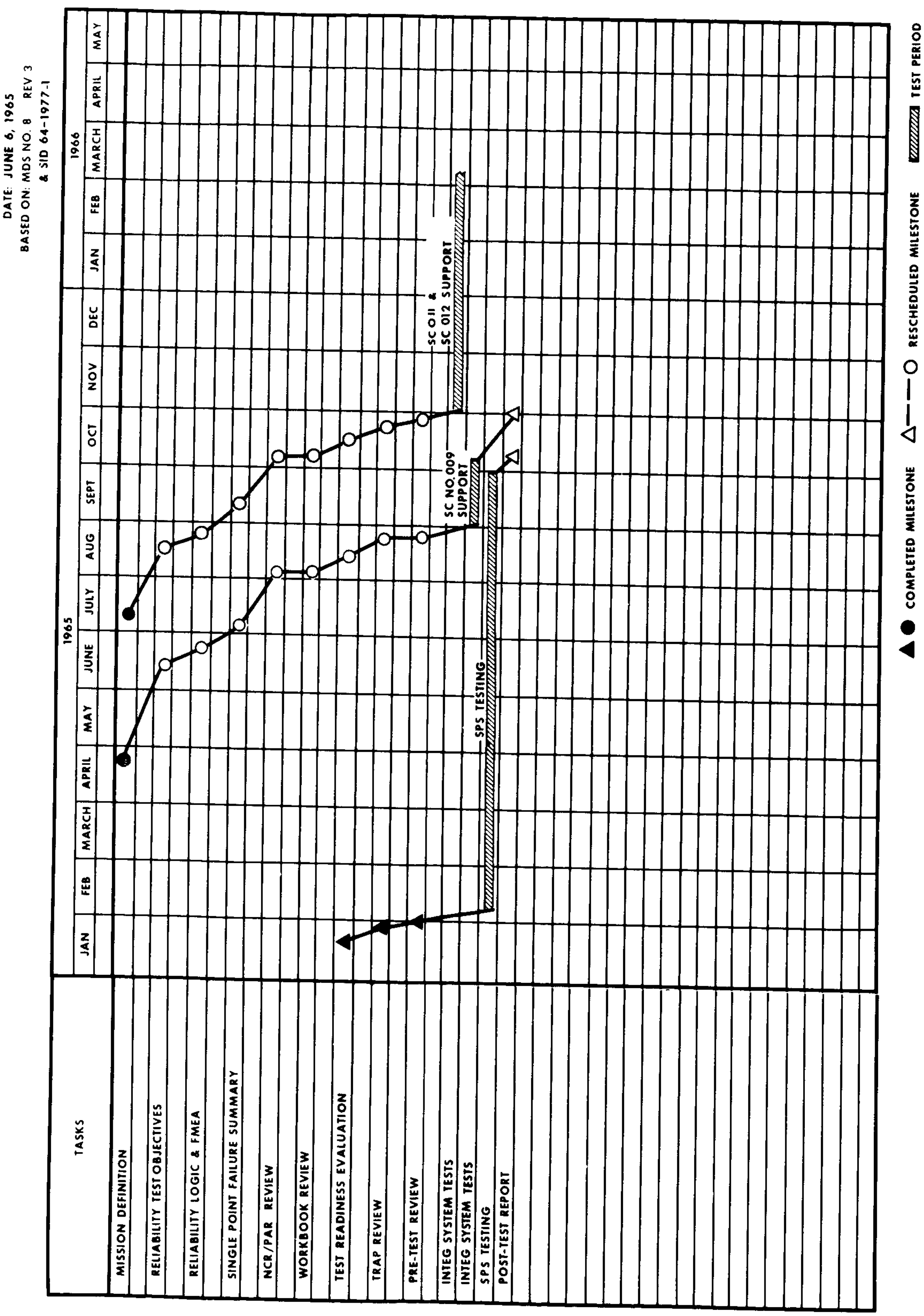


Figure 1-6. Reliability Support Schedule for Spacecraft 001

1.1.2.4 Boilerplate 12A

The mission for Boilerplate 12A was defined to verify the structural integrity of the command module forward bulkhead and egress cylinder in a hard roll-over water landing. One-tenth scale drop tests indicated excessive pressures would be applied to these areas. Boilerplate 12A was established to provide full-size tests under these conditions, through use of the command module from Boilerplate 12. The major reliability milestones are given in Figure 1-7.

1.1.2.5 Spacecraft 002A

The mission for Spacecraft 002A was defined to verify the command module's primary and secondary structural integrity, to determine the capability of equipment mountings, and to demonstrate crew support system attenuation under shock conditions. Spacecraft 002A was established as a land-impact vehicle using a modified, refurbished command module from Spacecraft 002. The major reliability milestones for Spacecraft 002A are given in Figure 1-8.

1.1.2.6 Spacecraft 004

The command module for Spacecraft 004 was determined to be unsatisfactory for static and thermal tests because of Materials Review action on the bonded structure. The Spacecraft 004 mission was reduced accordingly and the affected tests were rescheduled as Spacecraft 004A. The major reliability milestones for the reduced Spacecraft 004 mission are given in Figure 1-9.

The service module and command-service module fairing structures are in the test area for installation of strain and deflection gauge instrumentation. All handling, GSE, and data recording equipment is ready for operation. All pre-test reliability activities are completed for this first phase of testing.

1.1.2.7 Spacecraft 004A

The mission for Spacecraft 004A has been defined. The command modules for Spacecraft 010 and Spacecraft 004 will be exchanged and the remaining Spacecraft 004 tests will be completed. The major reliability milestones are given in Figure 1-10.

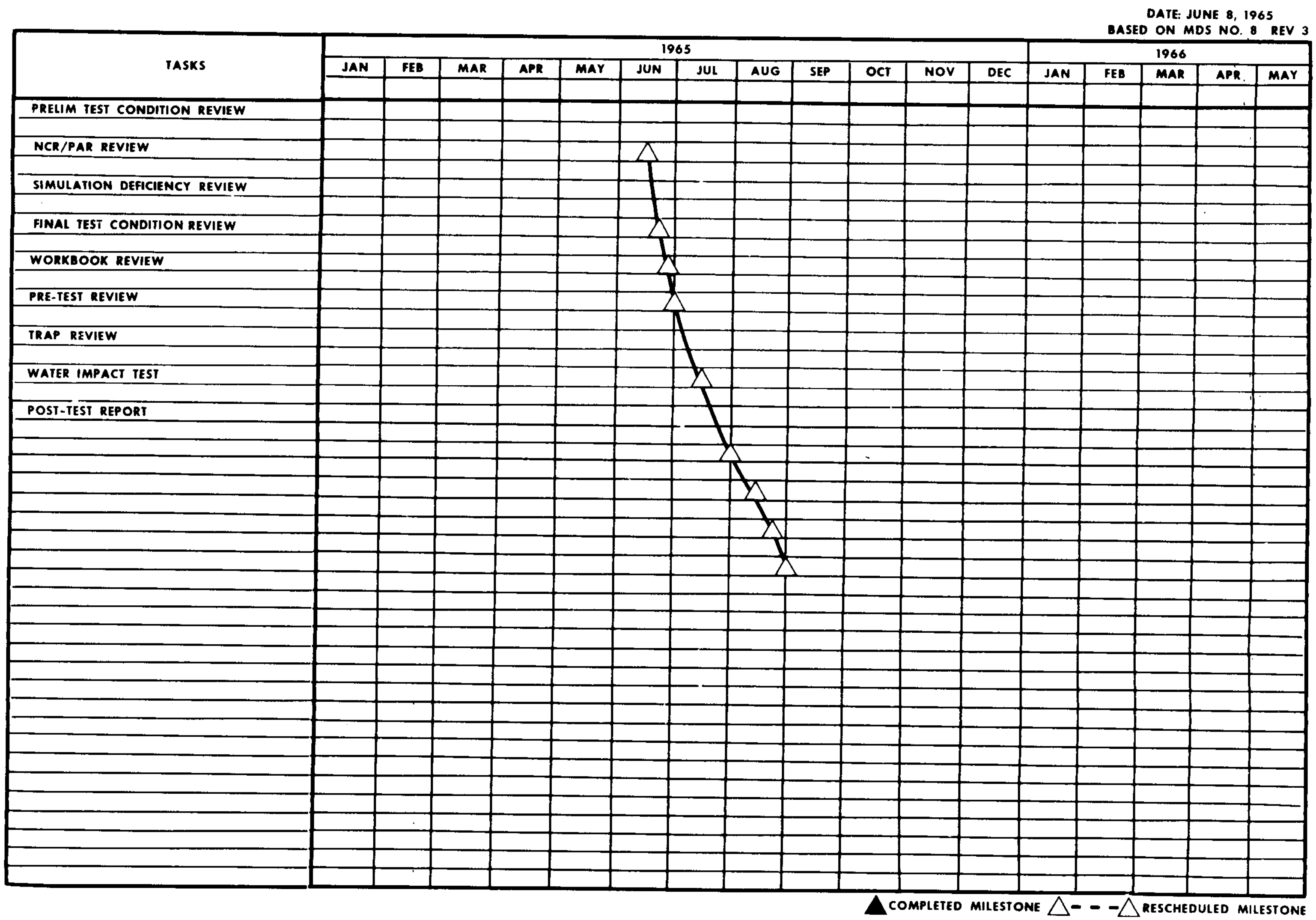


Figure 1-7. Reliability Support Schedule for Boilerplate 12A

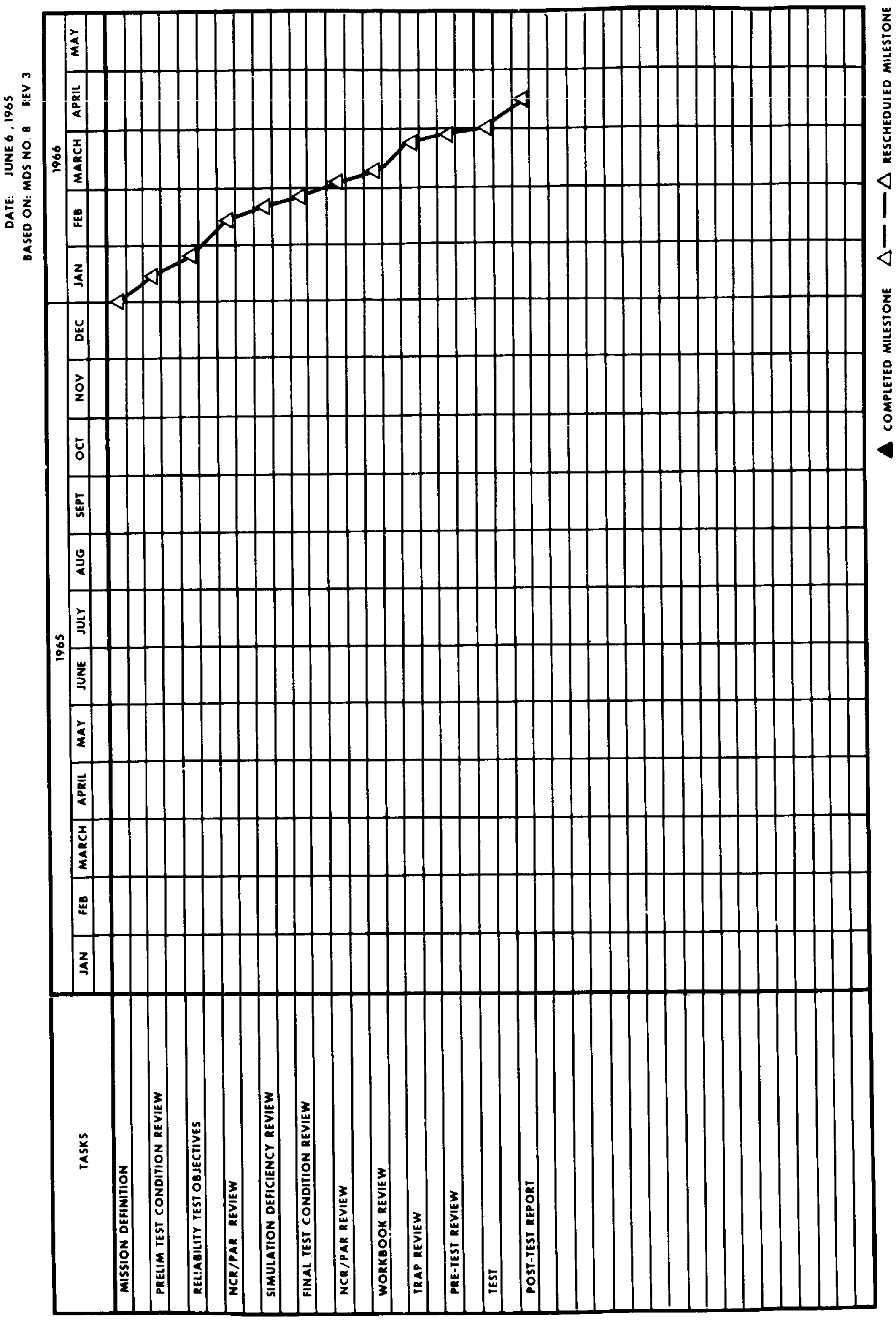


Figure 1-8. Reliability Support Schedule for Spacecraft 002A

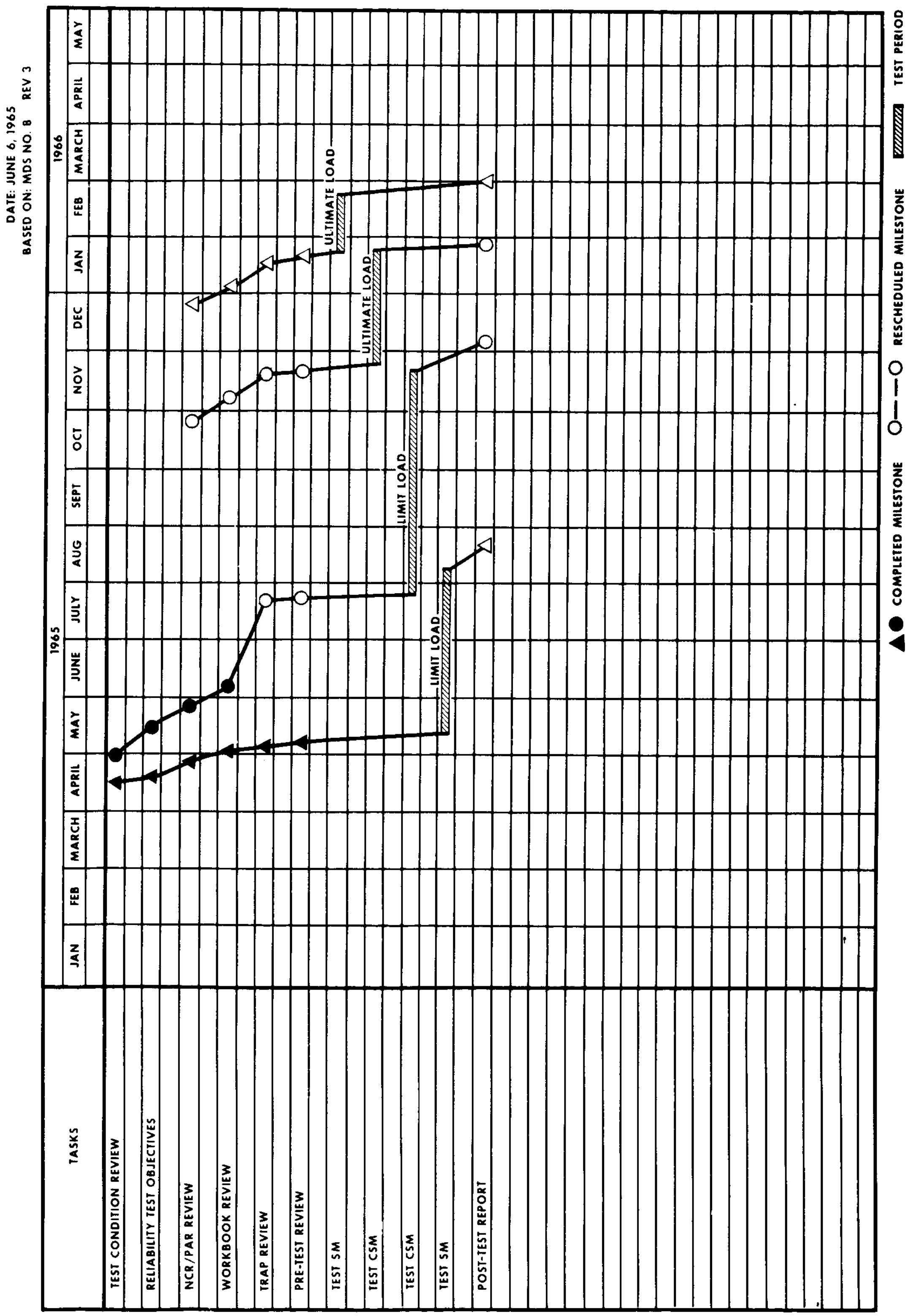


Figure 1-9. Reliability Support Schedule for Spacecraft 004

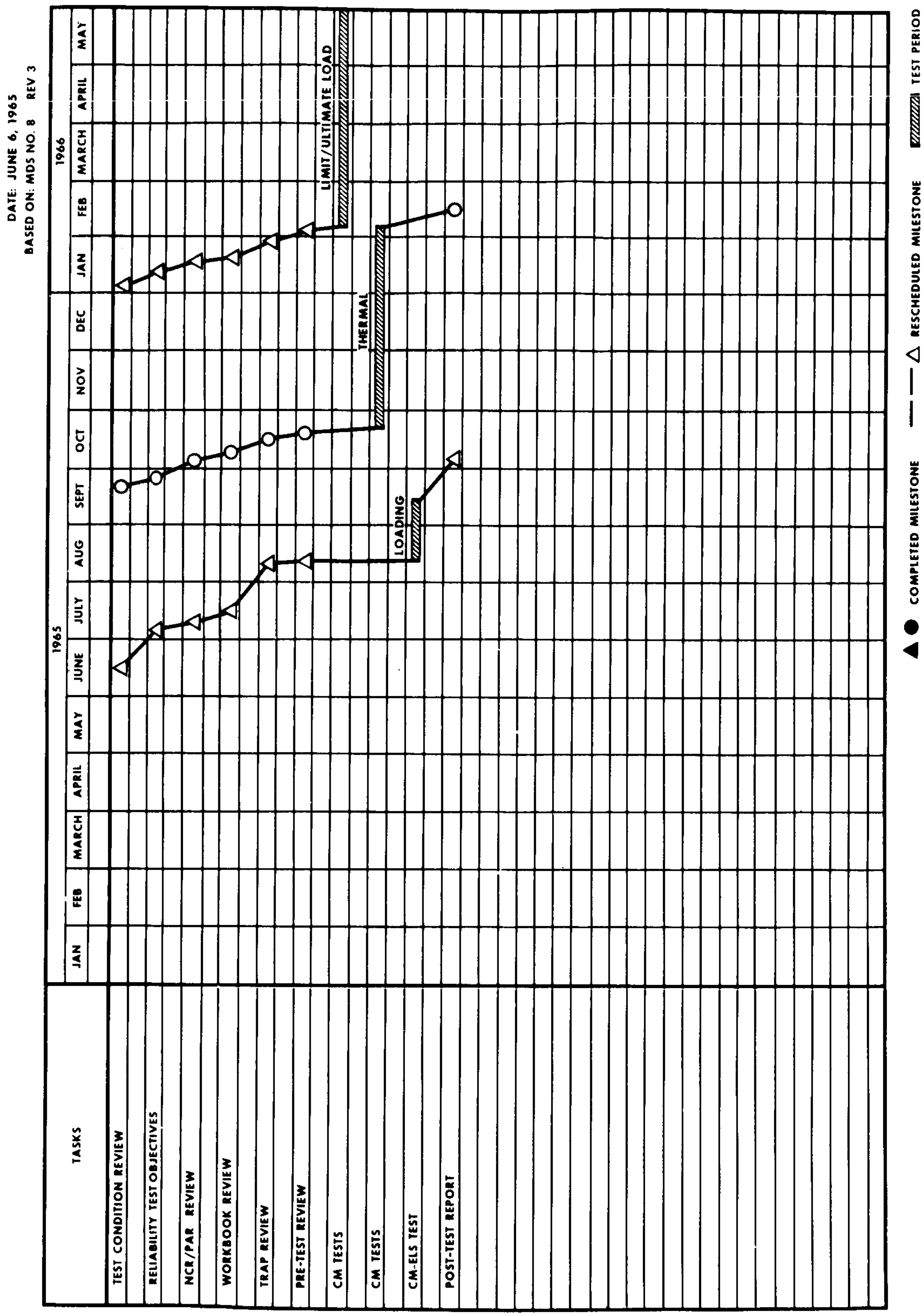


Figure 1-10. Reliability Support Schedule for Spacecraft 004A

1.1.2.8 Spacecraft 006

The Spacecraft 006 command and service modules were utilized to determine a meaningful vibration environment in which the integrity of spacecraft systems and the performance and control of the vibration facility could be demonstrated.

The Spacecraft 006 and quality verification vibration test (QVVT) equipment/facility configuration was in accordance with the Spacecraft 006 test plan (SID 64-1634) and with ATR 111011. The setup differs from subsequent scheduled usage because the operational vibration monitoring system was not available for this test. Also, the duration of the vibration test for Spacecraft 006 was greater than that of the test for operational vehicles. Significant differences between the Spacecraft 006 configuration and the configurations of subsequent vehicles to be subjected to the QVVT environment are as follows:

The subsystems were mass-simulated; consequently systems were not operating during QVVT.

The service module SPS fuel tanks contained 3564 pounds of water ballast. The Spacecraft 006 QVVT tests were accomplished in four calendar weeks and were concluded on 15 April 1965.

The Spacecraft 006 service module and command module were independently tested at S&ID. Dynamic test fixtures were used together with a multi-shaker excitation system. (See the QVVT facility equipment illustrated in Figure 1-11). These items of equipment were installed to support the QVVT processing of all Apollo flight spacecraft. Interim test instrumentation; data acquisition, and processing systems were provided by the Engineering Development Laboratories.

Maximum input levels applied to the command module were 1-1/2-g (peak) sinusoidal and 1-1/2-g (rms) random. The service module was subjected to a maximum of 1.0-g (peak) sinusoidal and 1-1/2-g (rms) random. The maximum input levels for random tests presented one-tenth the predicted space flight environment and one one-hundredth of the predicted boost environment in terms of acceleration power spectral density.

Because of differences between the Spacecraft 006 CM-SM and Spacecraft 009, and because of variations from one spacecraft to another, the data obtained in this test will have to be modified for subsequent vehicles.

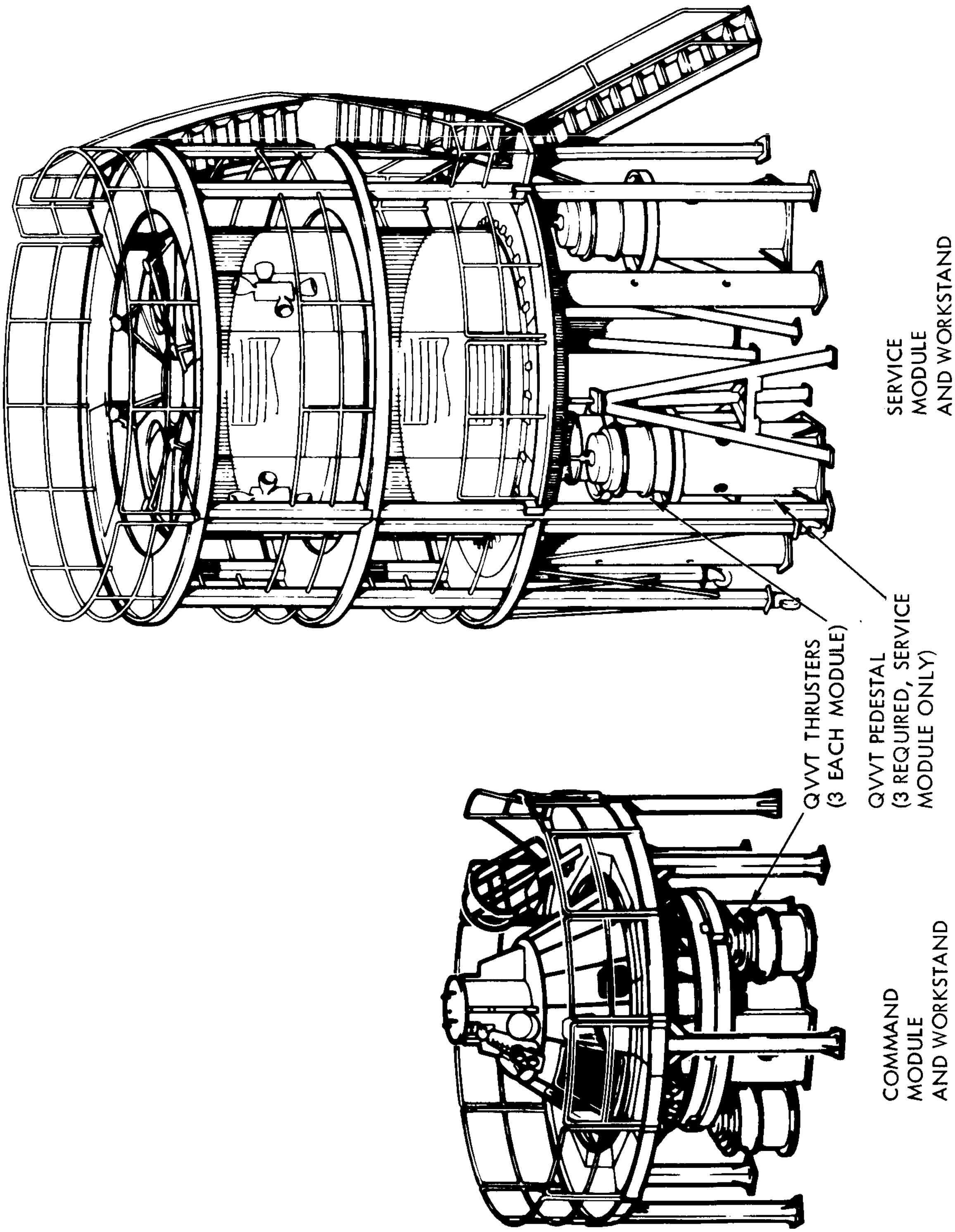


Figure 1-11. QVVT Facility Equipment

The test program demonstrated that random excitation can be applied to the command module and the service module over the desired 20 to 2000 cps frequency band. It was determined that the random excitation system has adequate range shading capabilities. However, it is essential that some of the dynamic instrumentation be duplicated in the initial flight vehicles for data correlation purposes in order to finalize the command module and service module random test spectra for all flight vehicles. The spacecraft milestone support schedule is shown in Figure 1-12.

1.1.2.9 Spacecraft 007

The first phase of Spacecraft 007 testing is nearing completion. Service module acoustic tests are proceeding on schedule with only two 180-decibel (at throat) random noise tests remaining. No structural damage has been detected although vibration resulting from air surges has been severe enough to break the bond between some accelerometers and the structure. Analysis of data is proceeding to determine vibration effects on the equipment in the service module. The spacecraft milestones are shown in Figure 1-13.

1.1.2.10 Spacecraft 008

Spacecraft 008 is the thermal-vacuum test vehicle for the Block I configuration. By the programming of various thermal-vacuum profiles and vehicle operational modes, data will be obtained for engineering evaluation of the Block I configuration and for mission support of the initial manned spacecraft flight tests. Tests on this vehicle are scheduled to begin in the second quarter of 1966 at MSC's Space Environmental Simulation Laboratory. The command module and service module are presently in process of assembly at S&ID, Downey.

During this reporting period the reliability support milestones shown in Figure 1-14, were defined. In addition, the Spacecraft 008 WORMS, an engineering review of unresolved design problems, was completed.

1.1.3 ASSOCIATE CONTRACTOR COORDINATION

1.1.3.1 MIT/IL Coordination

Information was acquired from the guidance and navigation associate contractor to update reliability logic diagrams for Block I and Block II vehicles. Differences in equipment configurations required for Block I series 0, Series 50, Series 100, and Block II were obtained for the purpose of refining the accuracy of logic diagrams for the applicable vehicles. Charts were acquired showing Apollo guidance equipment failure-rate summaries

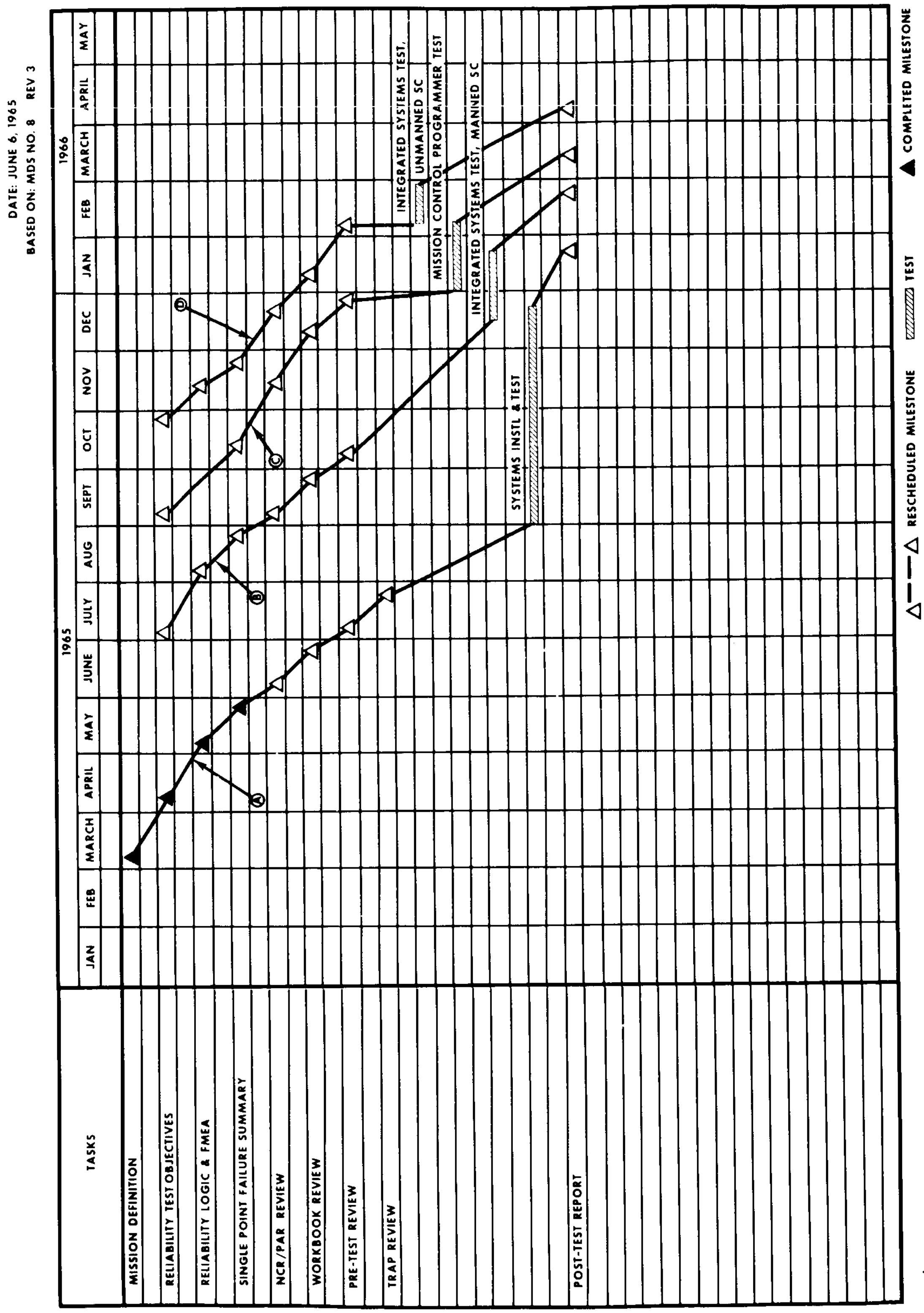


Figure 1-12. Reliability Support Schedule for Spacecraft 006

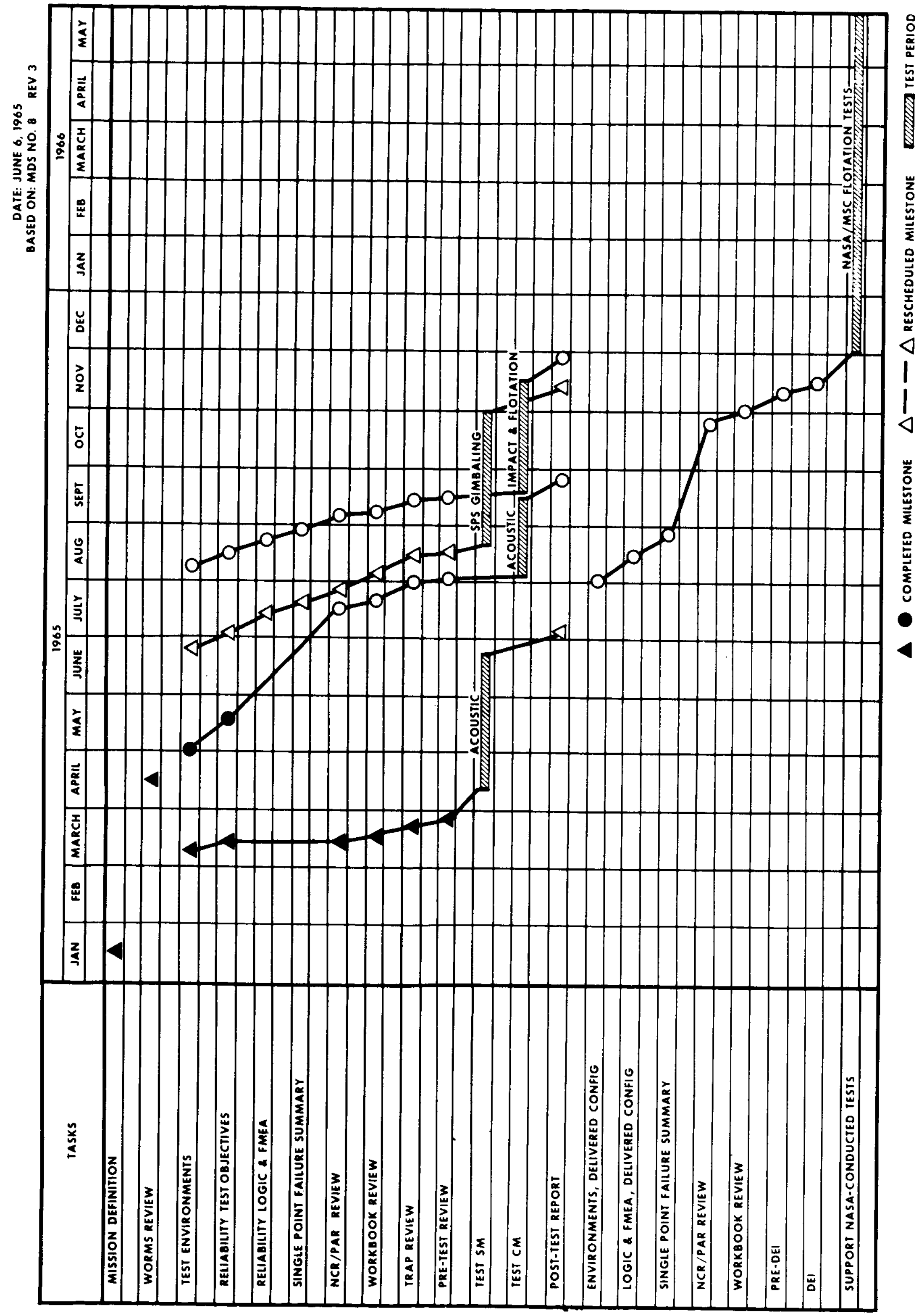


Figure 1-13. Reliability Support Schedule for Spacecraft 007

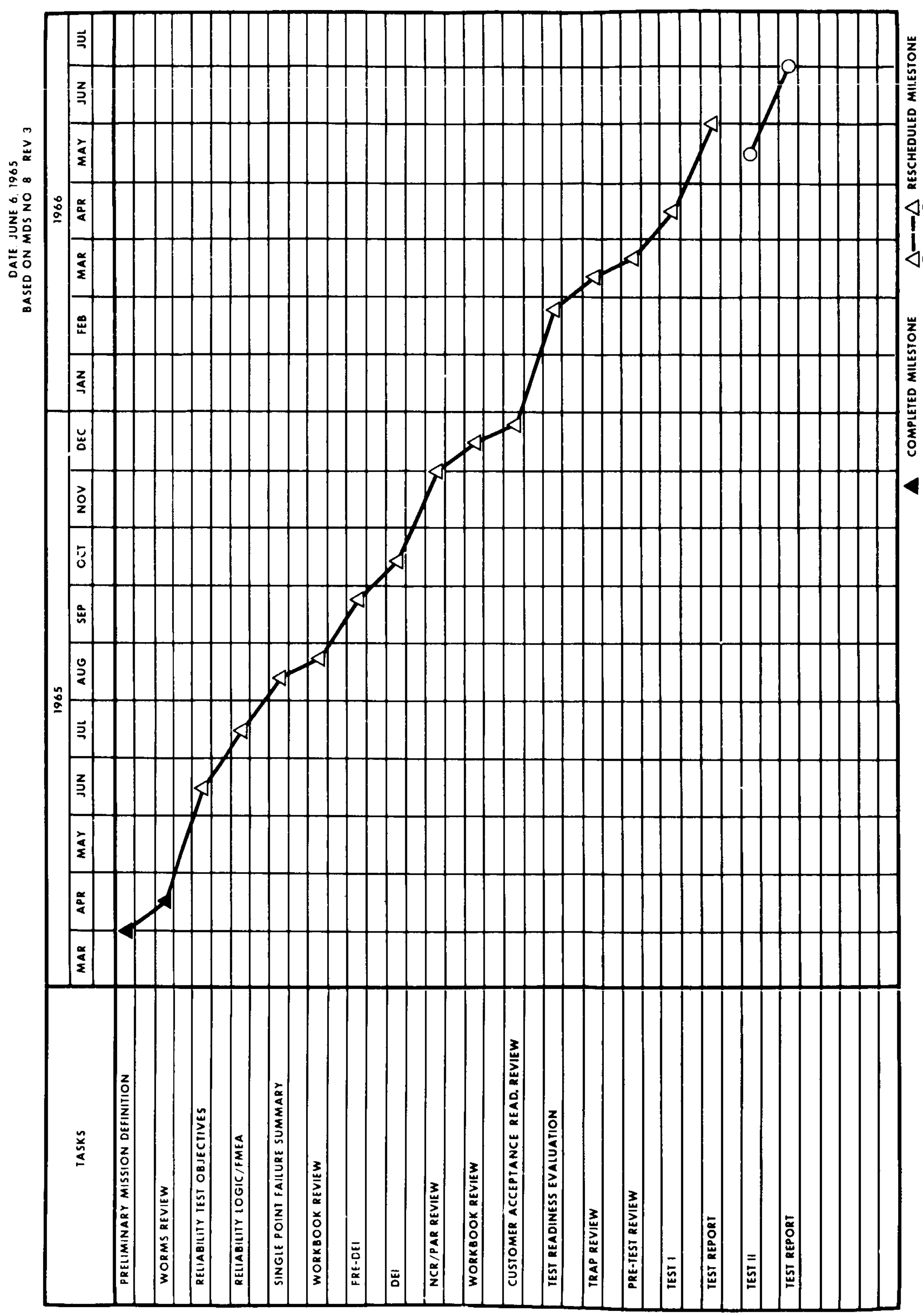


Figure 1-14. Reliability Support Schedule for Spacecraft 008

by functional modes. The data provided by these charts were used to facilitate the determination of subsystem marginal probability effects in the integrated electronics subsystems equipment network. Information was exchanged regarding estimates of equipment operating times and/or duty cycles for the Apollo mission planning task force design reference mission, as well as for Block I missions. Differences between S&ID and MIT/IL equipment operating times were evaluated. However, it was determined that resolution of these differences would be dependent upon receipt from NASA of more definitive information on the objectives of applicable missions. Information was obtained from MIT/IL regarding the expected values of the design operating life of guidance and navigation equipment time-significant items. The information was incorporated into the S&ID time-significant items specification which is designed to preclude the use as items for flight hardware of equipment which has been operated into the wear-out period.

1.1.3.2 NASA/MSC Support

Coordination was implemented between NASA, MIT/IL, and GE with regard to S&ID Apollo spacecraft vibration criteria. Reviews were presented dealing with the basis upon which Apollo environmental and test vibration levels were established. The objective of inquiries was to determine whether or not specified vibration test levels for Apollo guidance equipment were sufficient to preestablish reliable operation of this equipment under flight conditions and, if so, what margins of safety were incorporated. S&ID indicated that Apollo vibration levels had been established for applicable sections of the spacecraft as envelopes referred to confidence intervals established around regression lines of the Mahaffy-Smith prediction process. It was indicated further that these values represented optimum values wherein overall spacecraft weight was one of the primary parametric trade-offs under consideration. A recommendation was made that special studies be performed to determine the hysterisis effects of excessive vibration levels in order to determine allowable tolerance envelopes. Such studies may serve to determine and quantify the safety factors which have not previously been defined in Apollo vibrational analyses. However, on the basis of comparisons made between MIT/IL ND1002037, Apollo Airborne Guidance and Navigation Equipment Environmental Qualification specification, and NAA/S&ID MC999-051, Apollo Environmental Design and Test Requirements, it was determined that with the exception of gimbal-mounted electronics packages and navigation base shockmounts, MIT/IL vibration test levels for Apollo guidance equipment were compatible with S&ID values. In the excepted cases, MIT/IL's use of higher test levels than those called out by NAA/S&ID was not questioned. The additional information provided in these reviews included methods which were being employed by S&ID to integrate the results of test data into the qualification test program.

1.1.3.3 GAEC Coordination

Coordination with the associate contractor for the lunar excursion module centered around the mutual development of an interface control document (ICD) on reliability titled "Apollo Reliability Cooperative Plan for LEM Common Use/Spacecraft Equipment." Comments are being prepared by GAEC regarding the initial version of this ICD. The document delineates specific types of reliability data required for the development surveillance of and for the integration of common usage equipments.

1.1.3.4 Planned Activities

Planned activities include emphasized participation by Reliability in the establishment of the reliability aspects of interface control documents, more extensive efforts to obtain qualification test data on government furnished equipment from associate contractors for use in supporting the overall spacecraft reliability assessment model, and the preparation of reliability interface control documents to cover reliability interfaces in each operation with associate contractors.

1.1.4 SUBCONTRACTOR/SUPPLIER MANAGEMENT

1.1.4.1 Reliability Program Requirements

Specification MC999-0067, Apollo Reliability Program Requirements for Subcontractors and Suppliers, was revised to orient the subcontractor/supplier reliability programs toward the 11 reliability tasks derived from the NASA publication NPC 250-1 and SID 62-203, Apollo Reliability Plan, (15 February 1965, addendum 5 May 1965).

Implementation of the specification will result in the establishment of definitive reliability requirements in the subcontractor/supplier work statement and will establish uniform reliability program tasks throughout S&ID procurement for Project Apollo.

1.1.4.2 Proposed Budgets and Subcontractor Manpower Allocations

Funding requirements for 14 subcontractor/suppliers were prepared to define the level of effort needed to support the reliability program as specified in SID 62-203, Apollo Reliability Plan. These funding requirements will be used as a base point for evaluating and negotiating subcontractor/supplier proposed GFY 1966 budgets. Adherence to the funding requirements will (1) provide definitive direction to the subcontractor/suppliers, (2) enable subsequent management of their program, and (3) provide a uniform NAA rationale for the overall Apollo reliability program in consonance with customer direction.

1.1.4.3 Negotiations and Proposal Evaluations

Negotiations and proposal evaluations were discussed with Rocketdyne and Gibbs Manufacturing Co. during this report period. Their programs were evaluated against the 11 major tasks defined in MC999-0067A, Apollo Reliability Program Requirements for Subcontractors and Suppliers.

1.1.4.4 Resident Representative Activities

Apollo reliability resident representatives from Honeywell, Westinghouse, and Simmonds returned to S&ID for program updating. Topics discussed included audit procedures, responsibilities, and means of better communication with cognizant design and reliability personnel.

1.1.4.5 Subcontractor/Supplier Audits

Of the 42 subcontractor/supplier audits scheduled for GFY 1965, 34 have been completed, 26 of them having been performed during this report period. (See Figure 1-15.) The remaining eight audits will be rescheduled for GFY 1966. Audits to date have been most beneficial in informing and indoctrinating subcontractor / supplier reliability personnel in detailed Apollo reliability program requirements. As a result of the audit, recommendations were made for improvement, strengthening, and reorientation of their reliability program tasks. Information on specific audits is included under the subsystems sections. The subcontractor reliability management milestones are shown in Figure 1-16.

1.1.4.6 Document Review

The quantity of subcontractor/supplier documents reviewed during the report period are shown in Table 1-1.

1.1.5 DATA SYSTEMS DEVELOPMENT

1.1.5.1 Nonconformance Reporting System

By the end of the report period, the generator reporting system had produced approximately 2210 individual reports in support of the reliability program.

A feasibility study was completed indicating that a generator utility summary could be programmed. This system is conceptually designed to automatically assemble the data into classification in the computer and produce reports in various matrix and graphic formats.

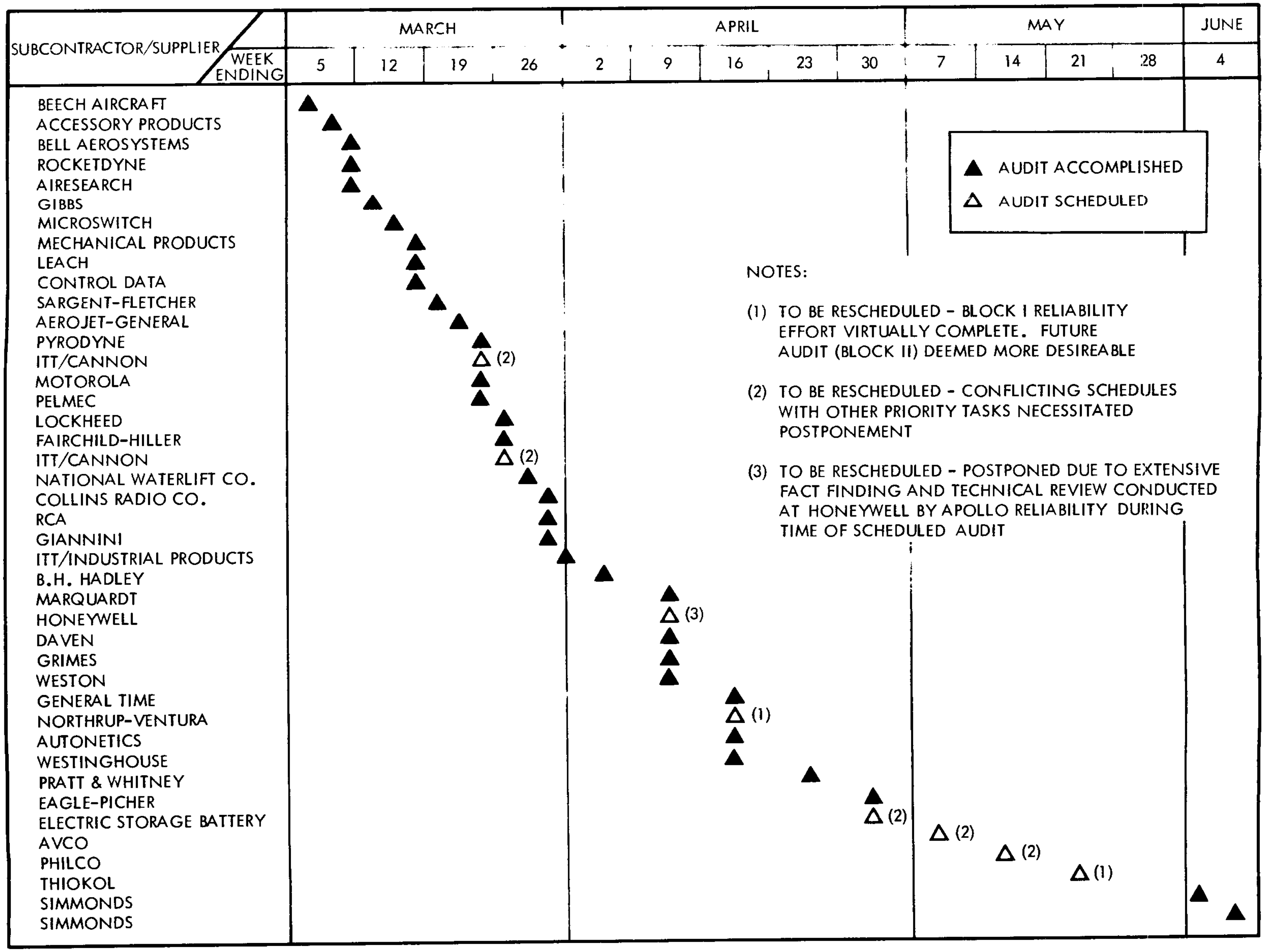


Figure 1-15. Subcontractor/Supplier Audit Milestones

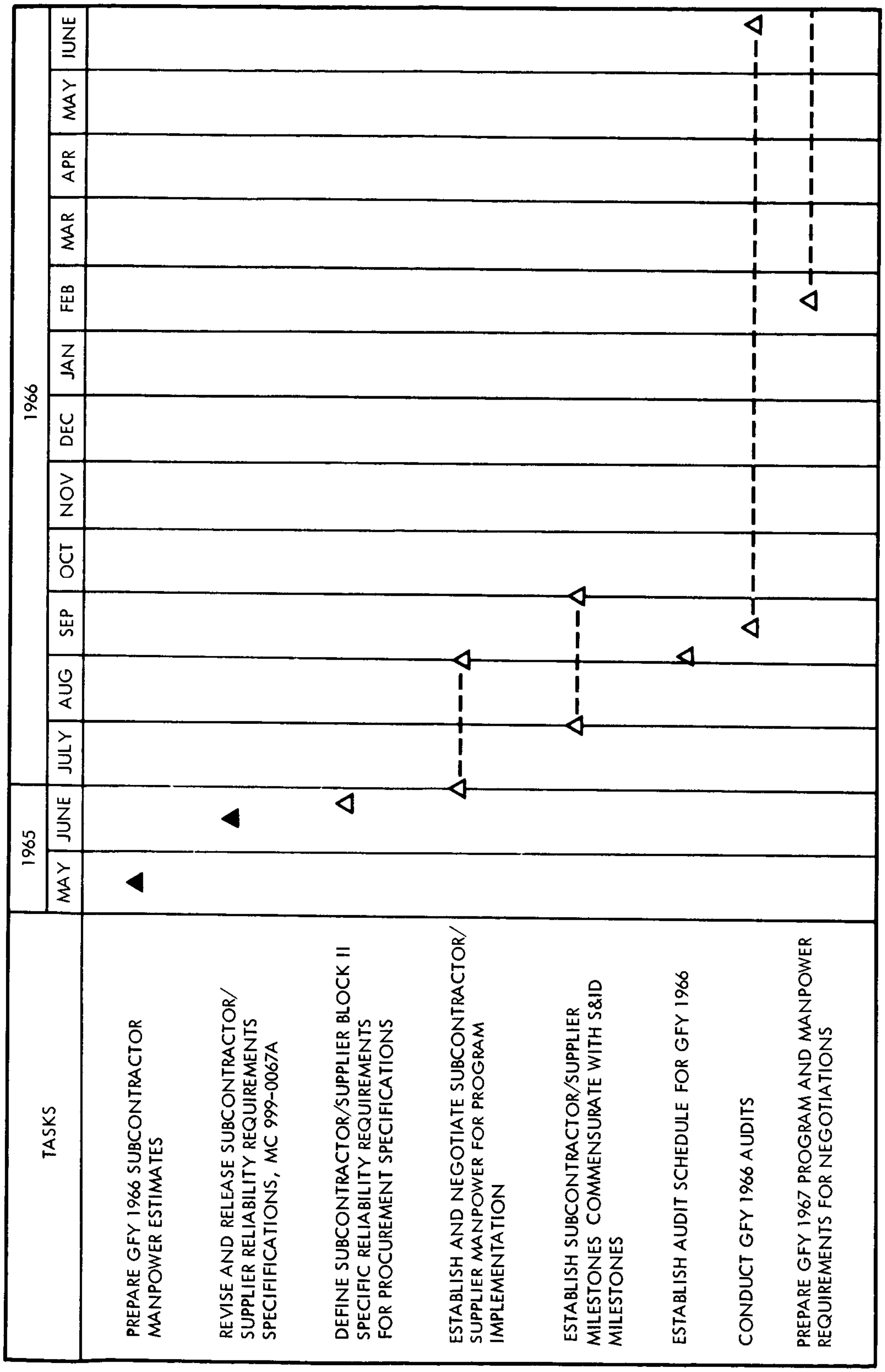


Figure 1-16. Subcontractor Reliability Management Milestones

Table 1-1. Subcontractor/Supplier Document Review

Document Type	Number Reviewed Prior to Quarter	Reviewed During Quarter	Total
Spacecraft subsystems			
Type I	4,255	1,771	6,026
Type II	14,675	2,845	17,520*
*Error last quarter increased this by 2000			

1.1.5.2 Apollo Operating Time System

As a phase in updating the Apollo operating time system, Revision B of Specification MA 0201-0077, Time Significant Item List and Requirements, was released. This specification requires that a systematic and complete time history be maintained on all time-significant equipment items, thereby providing better visibility and more valid data.

1.1.5.3 FAIR/TAIR Book Issuance System (FTBIS)

Phase I of the FAIR/TAIR book issuance system has been implemented. The mechanized FTBIS has been designed to provide rapid insight into the status of each book released by Technical Integration. Output reports indicate whether a book is still in the shop, has been returned to Technical Integration files, has been sent to Corporate Warehouse, or has been cancelled; a special report (Phase II) will provide the status and location of all the books for any particular end-item. This report will insure that all books will be accounted for in the end-item data package. The FAIR/TAIR books are used to collect identification, traceability, and configuration data as well as other elements for automated systems.

1.1.5.4 Traceability and Configuration System

New selective reporting techniques are being negotiated between T&QA and Information Systems. The present backlog of data amounts to approximately 98,000 records.

1.1.5.5 Performance Analysis Test History (PATH) Activities

An overall plan of action for updating and controlling the Apollo PATH program was prepared and transmitted to NASA/MSC. A supplementary, detailed, in-house plan was also developed delineating task assignments, responsibilities, and scheduled completion dates. Utilization of the program evaluation and review technique (PERT) was initiated as a PATH program control.

A supplementary proposal for application of PATH to acceptance checkout equipment (ACE) and unified S-band equipment was initiated. Two phases are delineated: (1) utilization of existing equipment with suitable computer programs and (2) development of display capability to provide data visibility as generated. This proposed program will permit extraction and evaluation of data recorded by automatic equipment, thus providing complete data accessibility from component testing through flight.

1.2 DESIGN SPECIFICATIONS

During the quarter, 987 procurement specifications and specification control drawings on spacecraft equipment were reviewed, in addition to 365 process specifications and 37 parts lists; 437 GSS equipment procurement specifications and specification control drawings were reviewed, in addition to 223 process specifications. Figure 1-17 which shows a summary of the design specification review includes the process specifications for spacecraft equipment in the vehicle specification accumulative total.

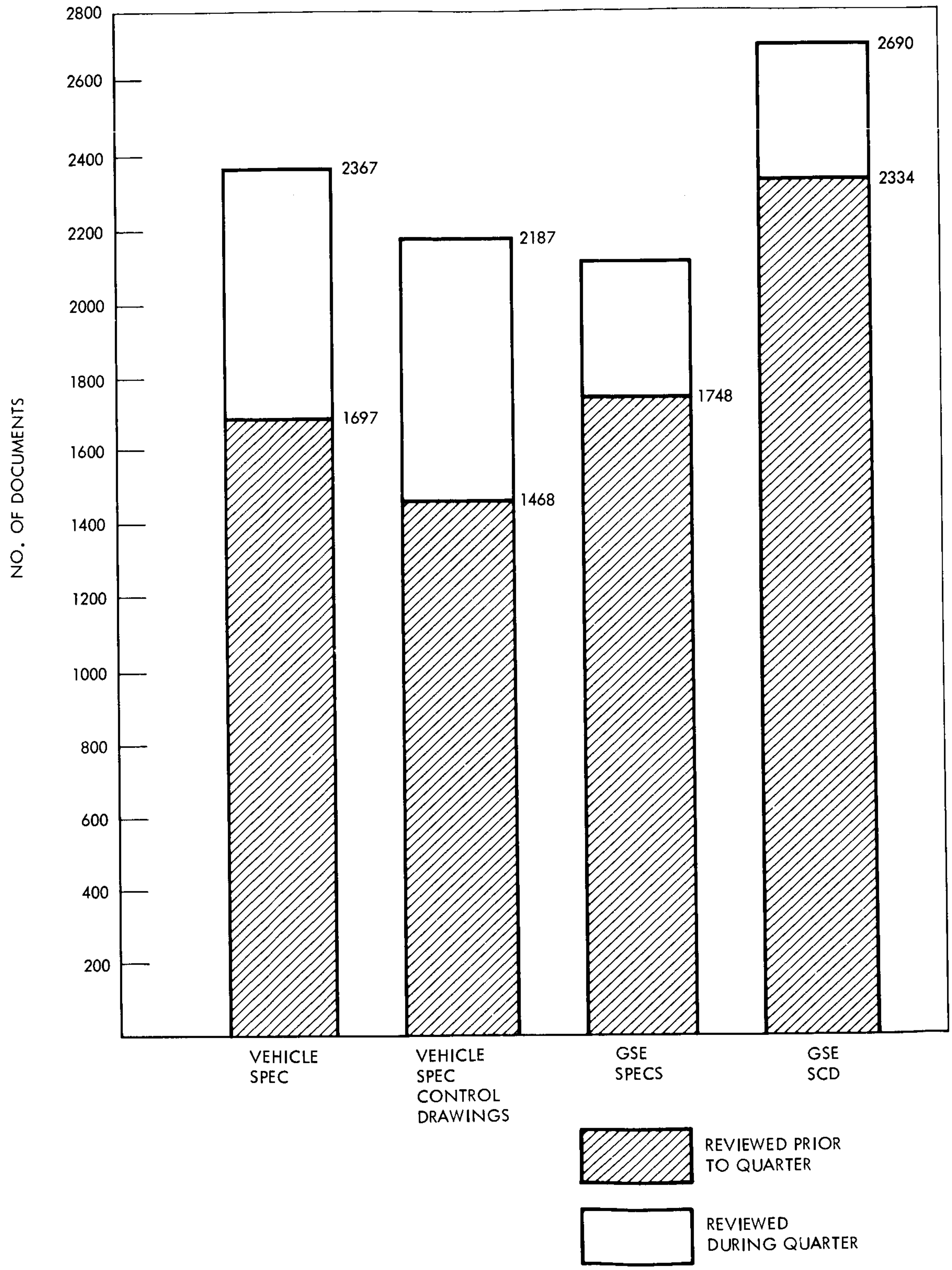


Figure 1-17. Design Specification Review

1.3 APPORTIONMENTS, PREDICTIONS, AND ASSESSMENTS

1.3.1 MISSION RELIABILITY MODELING DOCUMENT

The preliminary issue of the Apollo reliability modeling document was presented to NASA at the NAA/contractor model integration meeting 12 May 1965. The document contains a description of the current mission analysis computer program comprised of the subsystem conditional reliability model (SCRM) and the integrated system reliability model (ISRM). The mathematical models and their computer programs are utilized in performing system reliability prediction and apportionments. The document provides support on an action item assigned to NASA/MSC by the Space Technology Panel of the Presidential Scientific Advisory Committee as a follow-on to the Apollo program reliability briefing presented to the Panel in January 1965. The final issue of the Apollo reliability modeling document will be available in June 1965.

1.3.2 REVISED MISSION SUCCESS CRITERIA

Subsystem reliability design goals (Table 1-2) for the LOR design reference mission for reliability studies are based on the revised definition for mission success. This concept establishes mission success as the completion of the mission objectives, i.e., the planned lunar stay through rendezvous and docking—with no failures that would require an abort—and the subsequent safe return of the crew to earth. This criterion is currently being applied by Apollo Reliability.

Previous subsystem reliability design goals, as presented in the 13th quarterly report (SID 62-557-13), were based on the definition of mission success as the successful completion of the mission through minimum lunar stay (2 hours), with no failures that would require an abort and the subsequent safe return of the crew to earth. As directed by NASA/MSC in the selection of the current criteria, consideration was given also to the interpretation of mission success as the successful completion of the LOR mission through earth landing with no failure that would cause a mission abort.

1.3.3 BLOCK II PREDICTIONS

Reliability predictions for the Block II CSM will be made during the next quarter. These predictions will be based on the revised mission success criterion, i.e., the planned lunar stay.

1.3.4 BLOCK II APPORTIONMENTS

Command service module reliability analyses completed during the past quarter have established the mission success reliability goals for the total CSM and individual subsystems. The reliability goals are based on an 8.28-day LOR design reference mission and are in accordance with the latest mission success criteria (see Table 1-2).

The reliability requirements used in the mission success apportionment analysis for the boosters and the LEM are the NASA-defined reliability goals of 0.95 and 0.984, respectively. Mission success goals of 0.999 for the manned space flight network (MSFN) and 0.9999 for ground support systems were utilized also in achieving the overall spacecraft reliability goal of 0.90.

Subsystem crew safety goals were retained from the previously published apportionment (SID 62-557-13) since the change in mission success criteria (from minimum lunar stay to planned lunar stay) has no effect on crew safety reliability.

Planned activities for the Block II apportionments are to (1) provide mission success and crew safety reliability goals as inputs to the SID 64-1345, CSM Master End Item Specification (Block II); (2) perform reliability trade-off studies at the hardware level to determine hardware design goals; and (3) provide subsystem and hardware design goals for procurement specifications.

1.3.5 STANDARDIZATION OF LOGIC DIAGRAMS

A briefing to be presented to Apollo reliability personnel was prepared on the standardization of reliability logic diagrams for end-item vehicles. The briefing includes basic methods of construction, a standard set of ground rules for their preparation, and analyses of reliability logic diagrams.

1.3.6 APOLLO RELIABILITY FAILURE RATE FILE

A failure rate file system has been implemented to support the development of Block I and Block II vehicle apportionments and predictions. The failure rate file will provide compatibility and centralization in the following areas:

1. Failure rate source for Apollo reliability personnel

2. Documentation of failure rates used for reliability analyses, end-item apportionments, and predictions

3. Recommended sources of generic failure rate data and consistency in their application to Apollo hardware

4. Consistent methods for assigning environmental and application-severity factors

A list of failure rates used in the Block II mission mathematical model to support the spacecraft prediction analysis activity was prepared as the initial input to the failure rate file.

A review of current Apollo procurement specifications was completed to extract the numerical reliability design goals specified in the reliability requirements paragraphs. These goals have been placed in the failure rate file for historical reference and utilization in apportionment and prediction activity.

1.3.7 ASSESSMENTS AND ACCEPTANCE CRITERIA

1.3.7.1 Component Assessment

Reliability assessments were made on four major spacecraft components: char measurement system, MC 431-0026C; electronic control assemblies (ECA) – yaw and roll, ME 901-0168-0004 and ME 901-0167-0004; and the SPS helium pressure relief valve, MC 284-0027. Only incidental discrepancies were noted for the char measurement system. Corrective action taken on quality defects appears to be effective, and tentative approval of qualification is pending successful completion of vibration testing.

Various parameters of the ECA (yaw and roll) were marginal since several readings approached specification limits. However, only one condition may have a serious effect: when the change from the SCS ΔV mode to the SCS entry mode was made, a short burst of the No. 10 CM RCS engine occurred. The supplier contends that in test this short burst is intended but that in actual flight it will not occur. The condition will be investigated further. The ECA-pitch, ME 901-0166-0004, is identical with the ECA-yaw and will be assessed by similarity.

Based on a limited number of acceptance test units (23), the reliability of the helium pressure relief valve, MC 284-0027, was assessed at 0.998 at 60-percent confidence. No failures were experienced. If present performance is maintained during testing of additional units, the reliability will approach the reliability specification goal of 0.99985.

The assessment of the propellant/helium heat exchangers, MC 362-0008A and MC 362-0007A, given in the 13th quarterly report, indicated that two parameters – pressure drop and heat transfer – were marginal with respect to specification limits. These limits were reviewed by Apollo Engineering and wider tolerances were defined. The test data were compared with the new tolerances and mission requirements and yielded significantly higher reliability.

1.3.7.2 Launch Escape Motor Thrust Acceptance Criteria

Thrust acceptance criteria for requalification units from deliverable lots of launch escape motors, ME 467-0003, were modified for new temperature conditions. These conditions resulted from a change in specifications requested by NASA. In addition to accounting for possible sampling errors in the thrust mean ($\overline{X}$) and standard deviation (s), variability of the temperature regression line was also considered. The criteria were accepted by the subcontractor and, after a change in sample selection procedure, met the NASA random sampling requirements.

1.3.7.3 S/M RCS Engine Acceptance Criteria

Criteria for acceptance of three parameters of the SM RCS engine — specific impulse, average thrust, and oxidizer/fuel ratio — were developed for 0.90 reliability at 80-percent confidence. These criteria were patterned after those previously established for other engines in the Apollo CSM system. The criteria take into account the number of test units, variation in test instrumentation, and engine performance.

1.3.7.4 Functional Analysis and Assessment Models

The functional analysis assessment model, developed for the crew safety assessment of Spacecraft 012 and presented at the PSAC briefing, was further refined. Work is continuing on detailed delineation of logic, subfunctions, and data retrieval and collection methods.

Application of the current functional assessment method yields a preliminary crew safety assessment of 0.9735 for Mission 506A, the first lunar landing mission, based on a series of 15 functions. The assessment fulfilled an action item request from NASA stemming from the PSAC briefing.

A preliminary mission success functional assessment was performed for Spacecraft 009. An indicated reliability of 0.989 was obtained, based on data and logic for 14 functions. The assessment was made in support of a NASA request pertaining to a Spacecraft 009 briefing.

The functional assessment studies assumed the following:

1. All planned test and flights were successfully completed.

2. No unresolved problems remained, i.e., zero failures.

3. Expected functional reliability at 60-percent confidence was uniformly distributed to the functional blocks in series: $R_B = R_F^{1/n}$.

4. Logic blocks were combined in accordance with indicated redundancy.

1.3.7.5 Reliability Assessment Schedule

A proposed schedule for the preparation of reliability assessments was developed and is based on scheduled qualification dates. The Qualification Status List, SID 63-TO 695-322-2, and the Spacecraft Utilization List, SID 65-692-500-009, were used to determine components to be scheduled. Crew safety and mission-essential items were delineated. This schedule includes a series of eight sequential activities accomplished in performing an assessment. Manpower requirements are also delineated. Based on this information, a program of selective assessments was initiated.

1.3.7.6 Operating Time Cycles

A program was initiated in cooperation with Technical Integration for collection, summarization, and analysis of operating time/cycles for crew safety and mission-essential items the reliability of which is time/cycle dependent. A preliminary list of Spacecraft 012 components was prepared for incorporation into process specification MA 0201-0077B. Operating time-cycles applicable to these components will be evaluated in conjunction with failure information to obtain reliability assessment estimates. The list will be updated periodically for subsequent vehicles.

1.3.8 SPECIAL STUDIES

1.3.8.1 Boost Protective Cover Study

A study to determine the probability of abort failure resulting from the impact of hard parts of the boost protective cover (BPC) with vulnerable parts of the launch escape system (LES) was performed. The analysis was based on the probability of abort, of impact, and of critical damage if impact occurred. The study was based on a point-mass, volume-location analysis, with the assumptions of BPC breakup between 90 degrees and 180 degrees of CM LES rotation; on critical damage resulting from an impact angle within ±5 degrees of perpendicular; and on LES angular velocity of 180 degrees per second. Impact probabilities were calculated for all abort altitudes, and an overall probability of critical damage of two per million launches was computed.

A follow-on study, based on line-mass and area-location analysis (much more severe criteria), was undertaken. This study was designed to verify a parallel study conducted by NASA/MSC which yielded a higher failure probability. The LES angular velocity was assumed to be 120 degrees per second. The average impact angles and their range, as well as vector impact velocities, were calculated for various abort altitudes. These parameter values were transmitted to NAA Flight Dynamics for a more exact calculation of critical damage probability.

1.3.8.2 Parachute Riser Wraparound Study

Support was provided in the study of the probability of critical damage to the command module structure resulting from parachute riser wraparound. Reliability criteria were defined, design probability analyses were evaluated, and the graphical results of the analyses of cumulative load probabilities were provided. Numerical reliability requirements that would be compatible with the overall crew safety objective were defined. This definition was possible because the wraparound conditions can occur only during a launch abort below 120,000 feet. The probability analyses were generally approved, with the exception of the assumption of the linear distribution of toroid loads. These were found to be nonlinear when the load point was within 45 degrees of the -Z axis. Graphs of the results of the analyses will be transmitted in the forthcoming report to NASA/MSC.

1.3.8.3 Statistical Test Development and Evaluation of Shock-Absorbing Core

A statistically efficient test plan was developed to attain the maximum information about the shock absorbing-cores used in the crew couch. The Greco-Latin square technique was utilized in the development of the test to make possible the separation of outside variables from the variables of interest during data evaluation.

An evaluation was performed on the data results of the first set of development tests and the results were obtained through the technique described are as follows:

1. A static test could be used to determine the dynamic capability of the shock-absorbing cores.

2. There was a difference in capability from one core to the next.

3. The core centers varied from the core ends in crush strength.

Further test programs of modified core and/or test equipment will be carried out utilizing the developed statistical program.

1.3.8.4 Initiator Burst Pressure Limit Study

An analysis of the test data of the Space Ordnance System (SOS) initiator (ME 453-0009-0006) was made to determine the upper and lower limits to which burst pressure must conform to achieve a reliability of 0.999 at 80 percent confidence. The results of the study compared favorably with the specification limits of 650±125 lb.

Burst pressure data from another lot of initiators, tested at Pelmec, were submitted for comparison with the SOS data. The mean ($\bar{\bar{X}}$) and standard deviations (s) were significantly higher than those computed from SOS data. Because of the increased mean and variability, the limits calculated for Pelmec's data greatly exceeded maximum specification requirements. The difference in test results was attributed to Pelmec's use of a test setup different from that employed at SOS.

[redacted]

Table 1-2. Block II Reliability Apportionments
(LOR Design Reference Mission)

Subject	Mission Success Apportionment	Crew Safety Apportionment
Structures (all)	0.999999	0.999999
Heat shield	0.999960	0.999960
Launch escape	0.999946	0.999960
Separation	0.999973	0.999987
Parachute recovery	0.999950	0.999950
Earth impact and flotation	0.999975	0.999975
Docking mechanism	0.999963	0.999999
Electrical power	0.996307	0.999975
Emergency detection	0.999990	0.999999
Environmental control	0.995372	0.999999
Cryogenic storage	0.996108	0.999995
Space suits	0.999979	0.999997
Portable life support	0.999917	0.999999
Integrated electronics	0.977419	0.999897
Command module RCS	0.999704	0.999877
Service module RCS	0.998684	0.999999
Service propulsion	0.998464	0.999942

1.4 FAILURE MODE EFFECT AND CAUSE ANALYSES

The preliminary failure mode effects analysis (FMEA) for all spacecraft subsystems were released on Spacecraft 002 and 011. The Spacecraft 012 preliminary FMEA was initiated on all subsystems and will be completed during the next quarter. Preliminary FMEA's on Spacecraft 014, 017, 020 and Block II will be completed during the next quarter, together with the updated FMEA's on Spacecraft 011 and 012. Upon completion of each FMEA by Apollo Reliability and the respective design engineering group, FCA's will be initiated. The FCA's on the Spacecraft 002 and 011 subsystems have been partially completed, and the others will be initiated pending engineering coordination. Table 1-3 indicates the schedule of the FMEA activity.

During the report period 11 failure mode cause analyses (FMCA's) required and received followup action by representatives of cognizant Engineering, Quality Assurance, Quality Control and Material and Producibility Groups. Existing preventive action or recommended corrective action to preclude the failure modes from occurring were noted and approved. The preventive or corrective action on the 11 coordinated FMCA's is summarized below.

An example of a completed FMCA is shown in Figure 1-18.

1.4.1 SERVICE PROPULSION SUBSYSTEM, HELIUM PRESSURE REGULATOR (MC 284-0020)

It was recommended that the design of the controller stem be reviewed with the vendor to determine if a three-point guide (needle valve design) will reduce the tendency of the pin to drag or freeze in its guide. It was also recommended that the results of the design verification test of the regulator metering piston be evaluated. A post-mortem on the design verification test hardware will be made to determine if galling of rubbing surface and O-ring particle contamination is evident. The FMCA on the helium measured regulator did not include the pressure surge limiting device being developed by the vendor.

1.4.2 ENVIRONMENTAL CONTROL SUBSYSTEM, CABIN PRESSURE REGULATOR (ME 284-0144)

Similar devices have functioned with good reliability in the regulation of aircraft cabin pressure, and the design provides for redundancy of the

Table 1-3. Preliminary FMEA Support Schedule for Blocks I and II, 1965

Subsystem	Spacecraft					Blk II
	011	012	014	017	020	
Guidance & control	11 June	18 June	15 July	5 August	10 September	2 August
Environmental control system	28 May	11 June	July	August	September	22 June
Waste management	18 January	18 January	18 January	18 January	18 January	18 January
Earth landing	1 June	1 June	1 June	1 June	1 June	18 July
Sequencers	26 March	26 March	26 March	26 March	26 March	15 June
Cryogenics & fuel cells	3 June	3 June	3 June	3 June	3 June	14 June
Crew systems	20 January	20 January	20 January	20 January	20 January	20 July
Structures	August	August	August	August	August	9 August
Mechanical devices	1 June	1 June	1 June	1 June	1 June	19 June
Separation & pyrotechnic	28 May	28 May	28 May	28 May	28 May	15 June
Electrical power	26 May	4 June	20 July	5 August	5 September	19 June
Communications & data	7 May	4 June	20 July	5 August	5 September	11 June
Instrumentation	20 May	4 June	20 July	5 August	5 September	18 June
CM RCS	March	June	15 July	5 August	10 September	29 July
SM RCS	March	June	15 July	5 August	10 September	5 July
SPS	March	June	15 July	5 August	10 September	13 July
Launch escape	March	June	15 July	5 August	10 September	29 January
Caution & warning	18 June	15 June	15 July	5 August	11 September	2 August

1 Failure Mode from Reference FMEA, Criticality I & II, Minimum	2 Potential Cause of Failure Mode (Parts and Processes Comprising the Unit), Including Mechanics of the Failure	3 Preventive and Corrective Action Existing and recommended precautions established to preclude the failure mode from occurring or to reduce the probability, effect, etc. Includes design features, manufacturing and inspection techniques, maintenance plans and acceptance test plans, other quality assurance provisions, prelaunch check provisions, etc.
1. Hook terminals will not accommodate spacecraft wiring	1. Vendor's drawing B-56525 does not conform to specification control drawings ME452-0092, ME452-0060, and ME452-0061 with regard to terminals.	1. The terminals as delineated by B56525 are satisfactory. Engineering will revise the specification control drawing to conform to the terminal as formed.
2. Breakdown of insulation	2. The insulation material in which the terminals are imbedded in the header (B-56525) and the time of the dielectric strength test are not specified.	2. Engineering will instruct the vendor to specify the insulation and to add the time (60 sec) to the dielectric test.
3. Poor electrical connection of soldered joints	3. Vendor's drawing C56609 does not reference MSFC-PROC-158A nor MSC-ASPO-S-5C which apply per procurement specification MC452-0060 (the solder SN60 called out on the vendor's drawing conforms to QQ-S-571; however, the drawing does not specify the MIL-F-14256 flux nor the certification of personnel).	3. Engineering will instruct the vendor to add the applicable soldering specification.
4. Current leak between potted terminals	4. Vendor's drawing C56612 does not call out a specification nor specify the method of curing the epoxy potting compound.	4. Engineering will instruct the vendor to add the applicable material and curing specifications.

Figure 1-18. Example of a Completed Failure Mode Cause Analysis (Hermetically-Sealed Pushbutton Switch, MC452-0060, Master Events Sequencer)

1 Failure Mode from Reference FMEA	2 Potential Cause of Failure Mode	3 Preventive and Corrective Action
5. Switch jams (hangs-up) in actuated position	5. Spring (A56613) has the following insufficiencies:	5.
	a. Axial force (402) was unable to overcome friction of balls which are held by spring (A56607) against inside of the switch bracket (B56511) with a force of 11 oz.	a. Engineering will discuss the spring loads and the friction of the actuating mechanism with the vendor.
	b. Rust on detention balls (drawing B56611 call for carbon steel balls)	b. Materials and producibility states that as a result of perspiration handling of the balls during assembly can cause rusting. Engineering will discuss with the vendor the use of stainless steel balls.
	c. Insufficient clearance between detention housing, (A56522) 0.318 in. (worst case), riding inside swatch bracket (C56511), 0.403 in. inside dimension (worst case)	c. Engineering will investigate design clearances and the affect of staking upon these clearances.
	d. Pin guide (A56514) is not retained in slot in switch bracket (C56511) nor is it oriented.	d. Engineering will discuss retention and orientation with the vendor.
	e. Retaining ring (X Ring) slips off actuator shaft (B56518)	e. Reliability recommends the use of a Waldes "true-arc" type of retaining ring. Engineering will discuss with the vendor a more positive means of shaft retention.
	f. Failure (break) of actuator lever spring (A56691) (0.012 R is stress riser at point of greatest flexure)	f. Engineering will discuss with the vendor the possibility of increasing the spring bend radius and of attaching it to the opposite side of the actuator rocker arm.

Figure 1-18. Example of a Completed Failure Mode Cause Analysis (Hermetically-Sealed Pushbutton Switch, MC452-0060, Master Events Sequencer) (Cont)

1 Failure Mode from Reference FMEA	2 Potential Cause of Failure Mode	3 Preventive and Corrective Action
6. Excessive leakage of hermetic seal	6. Leakage rate is not specified on switch assembly drawing C56616	6. Engineering will instruct the vendor to add the applicable leakage rate.
7. Hook terminals will not accommodate spacecraft wiring	7. Details of the hook as delineated on vendor's drawings A56530, A56531, and A56698 do not conform to specification control drawing	7. Same as Item 1
8. Poor electrical connections of soldered joints	8. Vendor's drawings C56637, C56661, C56631, B56630, and B56629 do not reference MSFC-PROC-158A nor MSC-ASPO-S-5C which apply per procurement specification MC452-0060 (the solder SN60 called out on referenced drawings conforms to QQ-S-571; however, the drawings do not specify the MIC-F-14256 flux nor the certification of personnel).	8. Same as Item 3
9. Pushbutton too sensitive to actuation	9. Inadequate built-in mechanical resistance (Paragraph 3.2.16 of MC452-0060 calls out 60±15 oz.)	9. Engineering will instruct the vendor to specify the mechanical resistance of switch assemblies (C56638, C56639, and C56662).
10. Pushbutton will not operate within specified range of 60±15 oz compression.	10. Small particles of dirt or other contaminant entrapped between the housing (C56532) and pushbutton (C56492) (0.015 in. nominal clearance)	10. Reliability recommends the addition of a dust-proof boot. Engineering has investigated and determined there is no practical method of protecting the switches from dust particles which can be incorporated within the existing envelope and mounting dimensions.

Figure 1-18. Example of a Completed Failure Mode Cause Analysis (Hermetically-Sealed Pushbutton Switch, MC 452-0060, Master Events Sequencer) (Cont)

1 Failure Mode from Reference FMEA	2 Potential Cause of Failure Mode	3 Preventive and Corrective Action
11. Terminal block loose in housing	11. Repeated actuation of the switch may bend or shear the 0.125-in. wide tabs (C56532), engaging the 0.150-in. wide slot in C56529. With nominal dimensions of tab and slot, there is a 0.025-in. shuck resisted only by the tension of the tabs.	11. Engineering will discuss with the vendor the tab and slot tolerances and investigate a more positive and secure positioning and locking method.
12. Push button locked and inoperative (Item 15 in preliminary FMCA)	12. There is an interference fit under worst case conditions, between the housing (B56648) and the push button (C56652). (Dimpled guides in the housing are 0.990 $\pm$ 0.005 in. and the mating dimension of the push button is 1.000-0.005 in., resulting in a worst-case interference of 0.015 in.)	12. Engineering will instruct the vendor to adjust tolerances as required.
13. Terminal block loose in housing	13. The terminal block (C56650) is positioned in the housing (B56648) by a 0.090-in. wide x 0.050-in. deep detention and is locked in position by an 0.025-in. thick housing tab pressed into a slot in the glass-filled epoxy terminal block. Repeated cycling of the push button will tend to imbed the tab or detention in the terminal block and affect the position of the block relative to the push button.	13. Same as Item 11.

Figure 1-18. Example of a Completed Failure Mode Cause Analysis (Hermetically-Sealed Pushbutton Switch, MC452-0060, Master Events Sequencer) (Cont)

1 Failure Mode from Reference FMEA	2 Potential Cause of Failure Mode	3 Preventive and Corrective Action
14. Push button separation from housing	14. Retaining ring (RC309) failure or disengagement will permit separation of shaft (A56577) and the terminal block (C56650), resulting in separation of the bush button and housing.	14. Same as Item 5 e.
15. Dielectric breakdown	15. Vendor's part (drawing) No. B56526 does not meet requirements because of inadequate testing. The duration of the dielectric strength test should be specified.	15. Engineering will instruct the vendor to add duration of dielectric strength test to the drawing.
16. Breakage of flexible leads	16. No evidence of satisfactory performance is available due to the lack of test requirements. Both drawing 56526 and specification MC452-0060 should provide requirements for a flexing cycle test.	16. Engineering will discuss flexing of the leads with the vendor and alert the supplier in regard to the flexing requirements.
17. Electric flash-over between current-carrying parts or to ground	17. Vendor's parts may fail in the absence of the electric clearance requirements. Paragraph 3.2.5 of specification MC452-0060 should include clearance specifications. It is recommended that the expressions "over surface" and "through air" be used in place of "creepage" and "clearance."	17. Engineering does not consider the electrical clearance to be a problem as testing in accordance with Paragraph 4.4.1.3 and 4.4.1.4 of the procurement specification provides assurance that the current leak does not exceed specification.
18. Part destruction through excessive acceleration	18. Provide limit for acceleration resulting from both the tangential and radial component in specification MC452-0060 and on applicable vendor drawings.	18. Engineering will caution the vendor against exceeding the specification limit of acceleration tests.

Figure 1-18. Example of a Completed Failure Mode Cause Analysis (Hermetically-Sealed Pushbutton Switch, MC452-0060, Master Events Sequencer) (Cont)

regulating function. There were no significant malfunctions not discovered and subsequently corrected during process inspection or the acceptance test.

1.4.3 REACTION CONTROL SUBSYSTEM

1.4.3.1 Isolation Burst Diaphragm Valve (MC 251-0005)

The most significant failure mode is an internal leak in the closed position caused by cold flow of the Teflon burst disc seal ring; resulting in a reduction in sealing pressure which would require that the cap nut be retorqued after installation. It was recommended that the supplier use a Teflon-coated V seal to replace the seal ring and redesign the cap plug to provide for a nut instead of a flange.

1.4.3.2 Propellant Tanks (MS 282-0004, -0006, -0007, and -0008)

The analysis indicated that while the present design of the propellant tanks is representative of the present state of the art, a serious potential failure mode is present during vacuum or pressure evacuation of the bladder when the Teflon bladder material is forced against the 0.032-in. diameter holes in the dispersion tube. It was recommended that the vendor redesign the dispersion tube and continue efforts to improve the bladder material. It was also recommended that the bladder be replaced if the ΔP across the bladder inadvertently exceeds 40 psi during ground checkout.

1.4.4 MECHANICAL DEVICES, ASTRO-SEXTANT DOOR MECHANISM (V 16-550502)

The analysis indicated the need for a redefinition of current space flight plans in regard to the open or closed position of the astro-sextant doors, and redefinition and review of the door mechanism temperature profile. Evaluation of the adequacy of the bearing lubricant (Braycote No. 618) used in the various gear boxes between the inner and outer shells of the command module is also dependent upon this updated temperature profile.

It was recommended that the detail design of the locking plunger and latching device for the screw jack, which provides sequential latching of the doors, be discussed with the vendor for the purpose of improving the design.

1.4.5 RECOVERY SYSTEM

1.4.5.1 Forward Heat Shield Separation (V 16-595100)

The design and testing of the forward heat shield separation system were found adequate, as were the materials used with the exception of

O-rings. Reliability and Quality Control recommended and Engineering concurred that Specification MSFC-STD-105, which establishes the cure date and age-control requirements of O-ring material, be added to all applicable drawings.

1.4.5.2 Canard Thruster (V 15-590201 and V14-590220)

The O-rings used in this component conform to the age-control requirements of MSFC-STD-105. Reliability requested that the affects of acceleration loads on the pin-ended thruster assembly during launch abort be studied by Engineering.

1.4.6 MASTER EVENTS SEQUENCER

1.4.6.1 Push-Button Switch (MC 452-0060)

The analysis indicated that the vendor's drawings of the push-button switch were deficient with regard to specifications covering soldering, dielectric strength, mechanical resistance, flexing cycles, and leakage rate. The method of positioning the switch in its housing was not considered to be effective following repeated cycling of the push button. A stress riser was found in the rocker arm spring. These items will be discussed with the vendor and the necessary corrective action initiated.

A noted design deficiency is the lack of a boot or other means of preventing the entrace of dirt or dust particles into the small peripheral clearance between the push button and its housing. However, there is no practical method of correcting this deficiency on the present design.

1.4.6.2 Hermetically-Sealed Rotary Switch (MC 452-0049)

Of the 24 potential causes listed, one was deleted as nonexistent and satisfactory preventive action was taken on four items. Corrective action was noted for the lack of affinity of the silver-tungsten roller material for gold plate. The remaining 18 potential failure causes required discussion or investigation by Engineering before firm preventive or corrective action can be delineated on the FMCA.

Engineering will make a thorough study of the supplier's detail drawings and discuss the potential failure causes with the supplier to determine if the design or reliability can be improved.

A final FMCA review will be made following a discussion between Engineering and the supplier during the next quarter.

1.4.6.3 Toggle Switch (MC 452-0050)

Analysis of the toggle switch indicated the present design was subject to several failure modes which made it totally unreliable. It was recommended that this switch not be used for any manned vehicle and that a second source of supply be developed for a positive-action type of toggle switch.

1.4.7 EARTH LANDING SUBSYSTEM, CIRCUIT BREAKER (ME 454-0011)

The review indicated that the circuit breaker configuration did not provide the required protection of the wiring because it was placed ahead of circuit branches which were rated less than the breaker.

The review also indicated the circuit breaker was used as a switch rather than a circuit breaker and that it was not dependable for use in the uprighting of the command module after landing.

It was recommended that the circuit breaker be replaced with one or more switches to increase the reliability of the uprighting system.

1.5 OPERATIONAL READINESS STUDY

At the conclusion of the 4-month Operational Readiness Study by Apollo Reliability, Operations Analysis Systems Engineering, a briefing was presented to NASA/MSC on 24 May 1965 at S&ID, Downey. The briefing agenda included the following items.

1. Review of the operational readiness effort
2. Explanation of the operational readiness evaluation procedure for Apollo ground support equipment
3. Delineation of the computer program employed and resulting trial computations

The results of the 4-month study included development of operational readiness methodology for Apollo ground support equipment. To extend the operational readiness concept to the complete Apollo program, the following recommendations were made.

1. Continue the study for development of methodology for evaluation of Apollo spacecraft
2. Develop methodology for total Apollo space vehicle operational readiness evaluation
3. Establish an official Operational Readiness Evaluation Task Team
4. Require incorporation of operational readiness evaluation in the flight readiness review for each spacecraft

A final report on the results and recommendations of the Operational Readiness Study, SID 65-885, is in publication and will be issued during the next quarter.

1.6 DESIGN REVIEW

Subsystem design reviews completed during the reporting period include:

Subsystem	Completed
Command module - service module reaction control	16 March
Stabilization and control	25 March
Command module - service module structures	30 March
Launch escape	6 April
Service propulsion	15 April
Instrumentation	20 April
Sequencers	29 April
Guidance and navigation	6 May
Communications	13 May
Data	1 June

Reliability was assigned 11 action items at the reviews, 8 of which are complete and 3 are in process.

The following subsystems are scheduled for review during the next quarter:

Impact and flotation
Displays and controls
ACE carry-on
Electric power - power distribution, Block II
Environmental control (including radiators and coldplates)
Telecommunications, Block II
Electrical power - fuel cells and radiators, Block II
Instrumentation - operational, Block II
Environmental control - oxygen supply and pressurization suit, Block II
Electrical power - cryogenic storage, Block II
Telecommunications - antenna system
ACE - servicing
Environmental control - command module pressurization and temperature control, Block II
Structure - command module, Block II
Service propulsion - storage and feed, Block II
Reaction control - command module
Stabilization and control, Block II
Structure - service module, Block II

1.7 FAILURE REPORTING, ANALYSES, AND CORRECTIVE ACTION

1.7.1 NONCONFORMANCE REPORTING SYSTEM

During the past quarter, the nonconformance reporting system has been revised and implemented throughout S&ID. Policy J-403, dated 6 May 1965 replaces J-403, dated 20 February 1964. This policy establishes the responsibilities and outlines the methods for reporting, processing, analyzing, recording the findings, recommending corrective or preventive action solutions, and monitoring the resultant action taken on nonconformances. The revised policy establishes responsibility for:

Material Review Disposition (MRD) System, J-403.1

Problem Action Record (PAR) System, J-403.2

Supplier Analysis of Components, J-403.3

Failure Analysis of Customer Returned Items, J-403.4

The problem action record (PAR) system is maintained for reporting failures and unsatisfactory conditions at the time of occurrence or observation, performing problem analysis, and establishing preventive action solutions to improve the reliability of the deliverable products. The revised system places the responsibility for S&ID failure reporting and the assuring of prompt corrective action in the hands of the Apollo Reliability Department, including the handling of unsatisfactory conditions affecting product reliability. To date, seven Reliability investigation engineers are monitoring Apollo areas for failure and unsatisfactory conditions, and one engineer is assigned to the PAR control desk to handle both S&ID and supplier failure reports. Based on the current and anticipated workload, it is expected that additional Reliability investigation engineers will be required, especially to provide proper coverage for a second- and third-shift operations.

A revised procedure relative to supplier analysis of failed components and a revised Supplier Failure Analysis Report (Form 925-R) have been drafted and are now being coordinated with concerned departments. It is anticipated that the procedure will be issued during the next report period.

The failure reporting system is being investigated to determine what changes are needed to obtain the capability to isolate all failures involving a given component part and to compile multiple failures of the same piece part. A study is also in progress to provide better functional interface between the various organizations involved in the failure reporting system.

1.7.2 FAILURE VISIBILITY

As of 7 June 1965, 29 magnetic tapes have been forwarded to the Houston, Texas, facility. The tapes carry all failure data originated by S&ID and suppliers relative to the Apollo program.

During the period March 1 to June 1, a total of 504 ground support equipment and 440 spacecraft failure reports were received. Of the ground support equipment failure reports, 434 were S&ID originated and 70 were subcontractor/supplier originated. Of the spacecraft failure reports, 350 were supplier originated and 90 were S&ID originated. Figures 1-19 through 1-33 display failure information on the 11 major subsystems, certain boilerplates, Block I spacecraft and the total program.

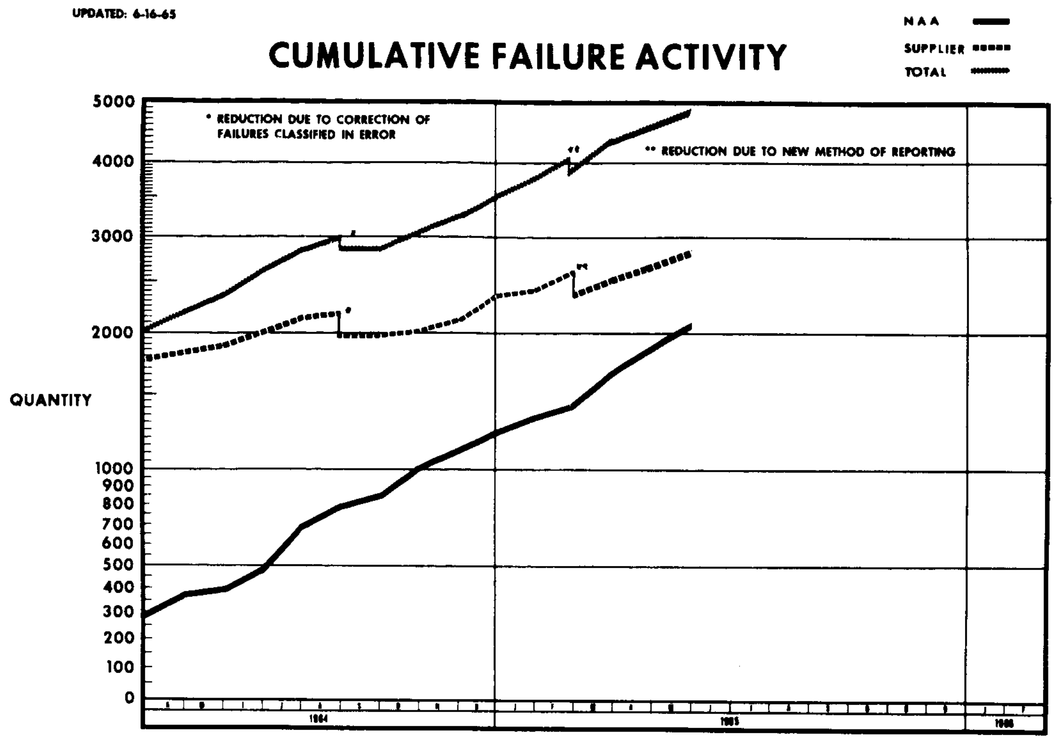


Figure 1-19. Cumulative Failure Activity

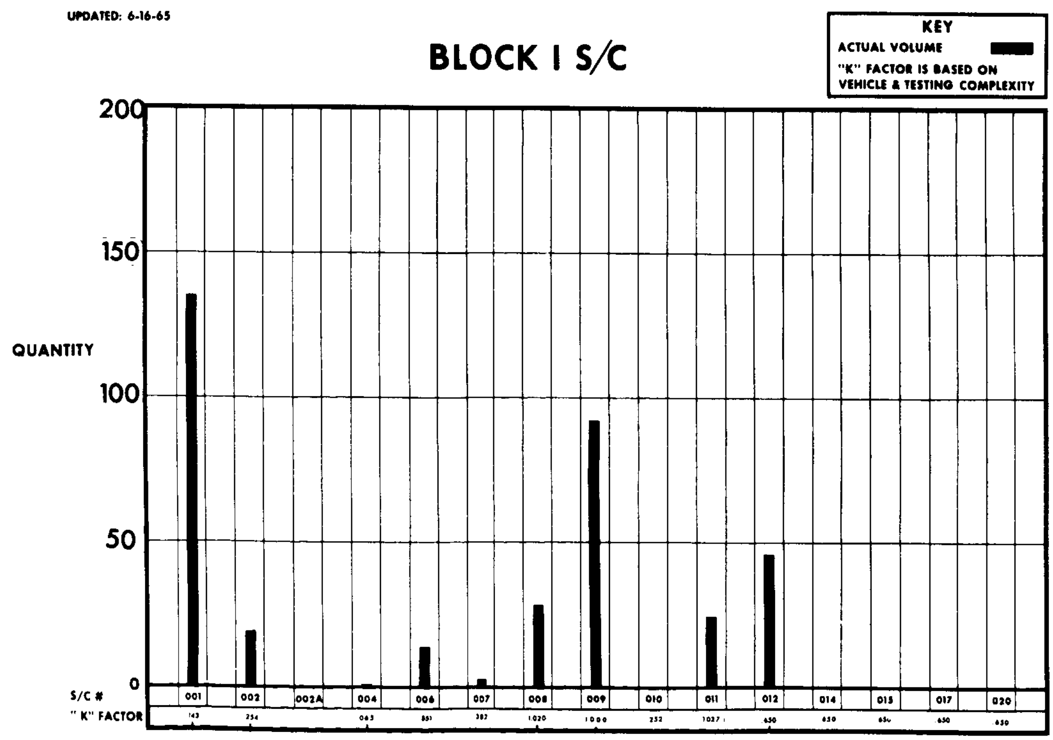


Figure 1-20. Block I Spacecraft Failures

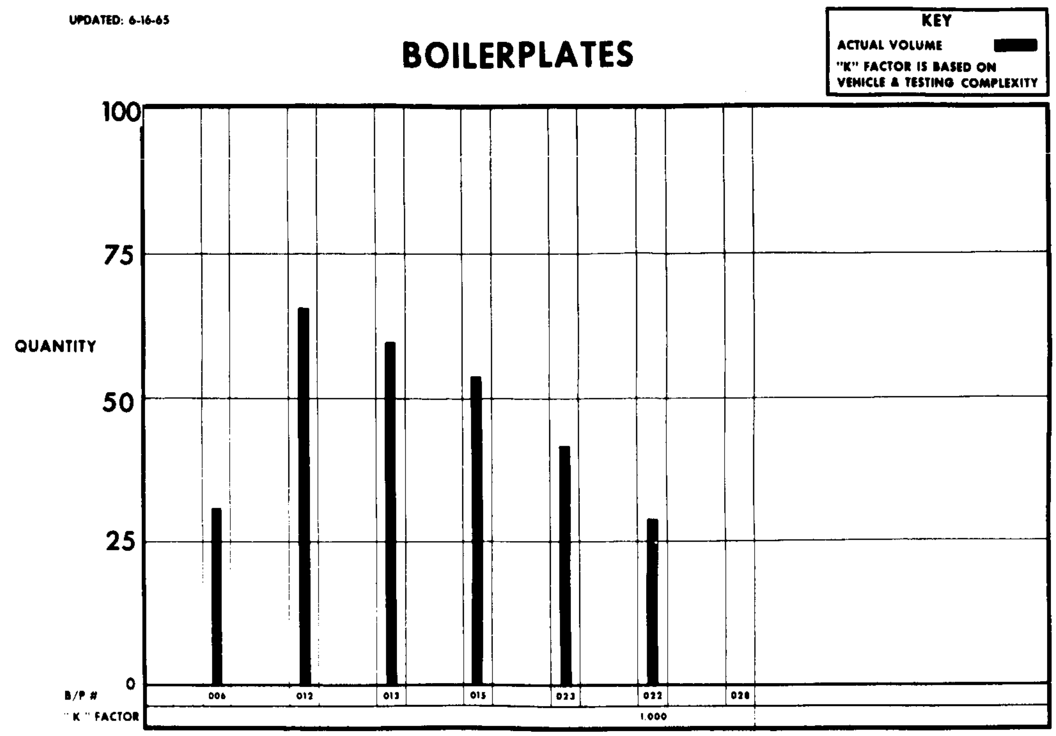


Figure 1-21. Boilerplate Failures

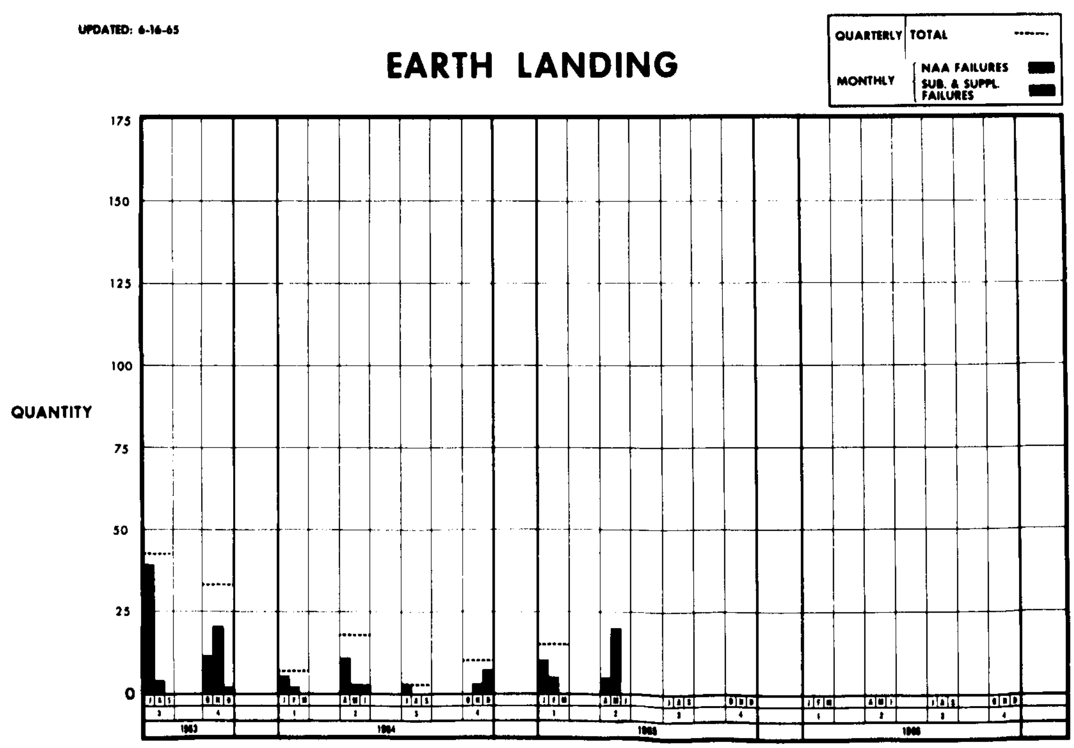


Figure 1-22. Earth Landing Subsystem Failures

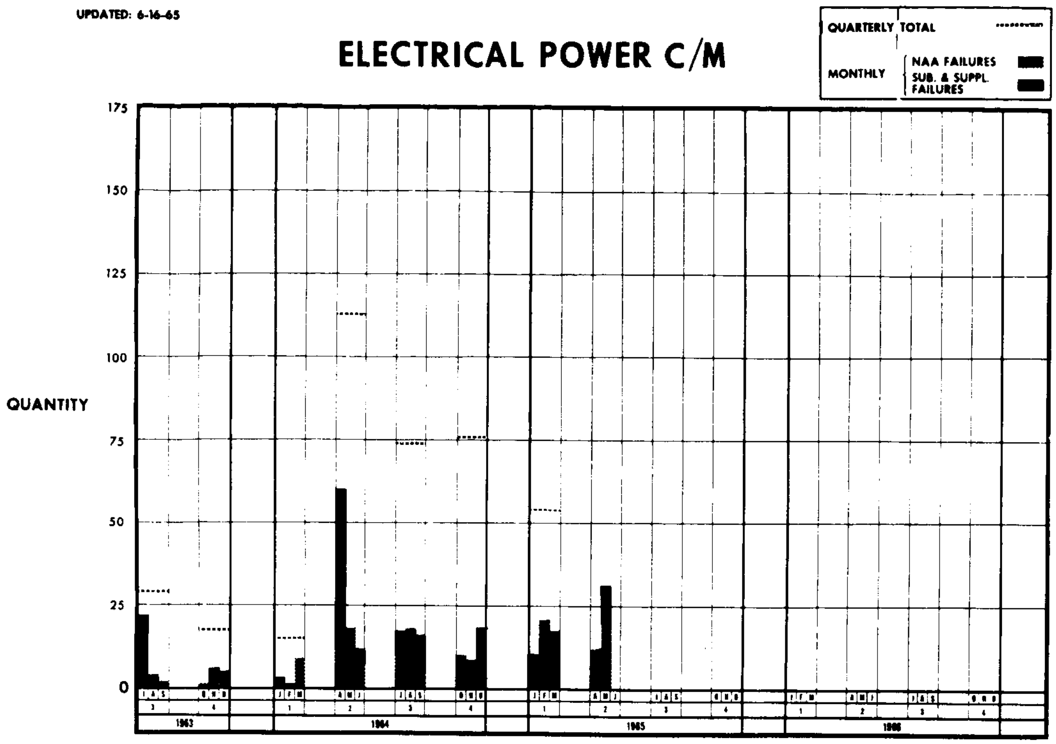


Figure 1-23. Electrical Power Subsystem Failures

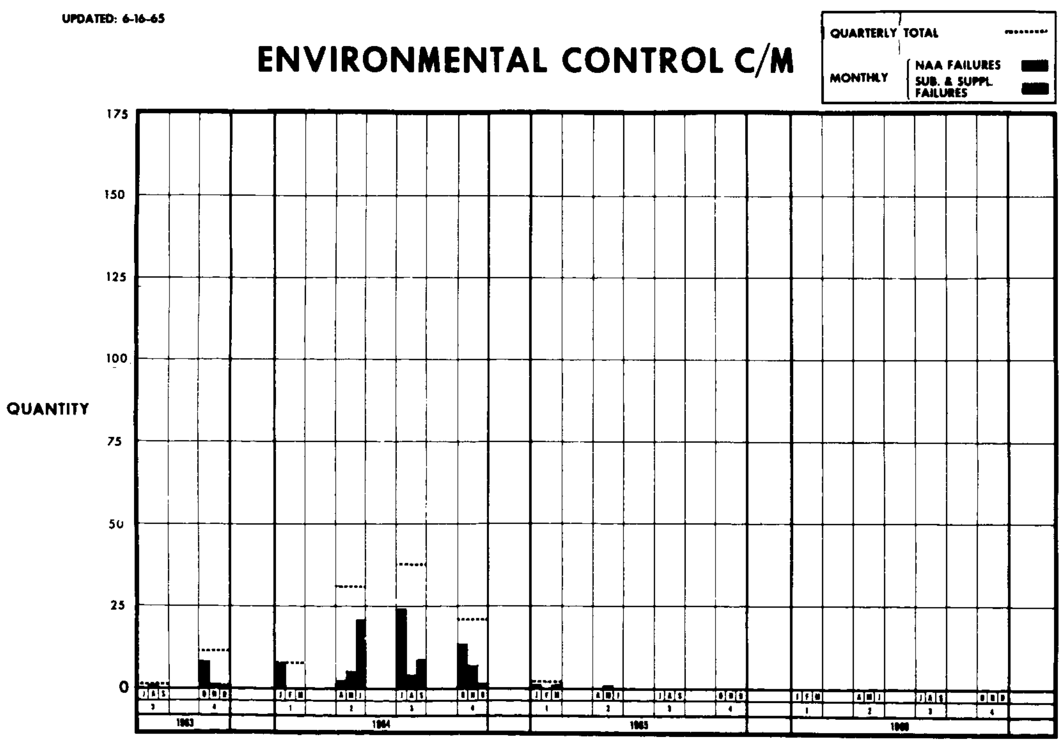


Figure 1-24. Environmental Control Subsystem Failures

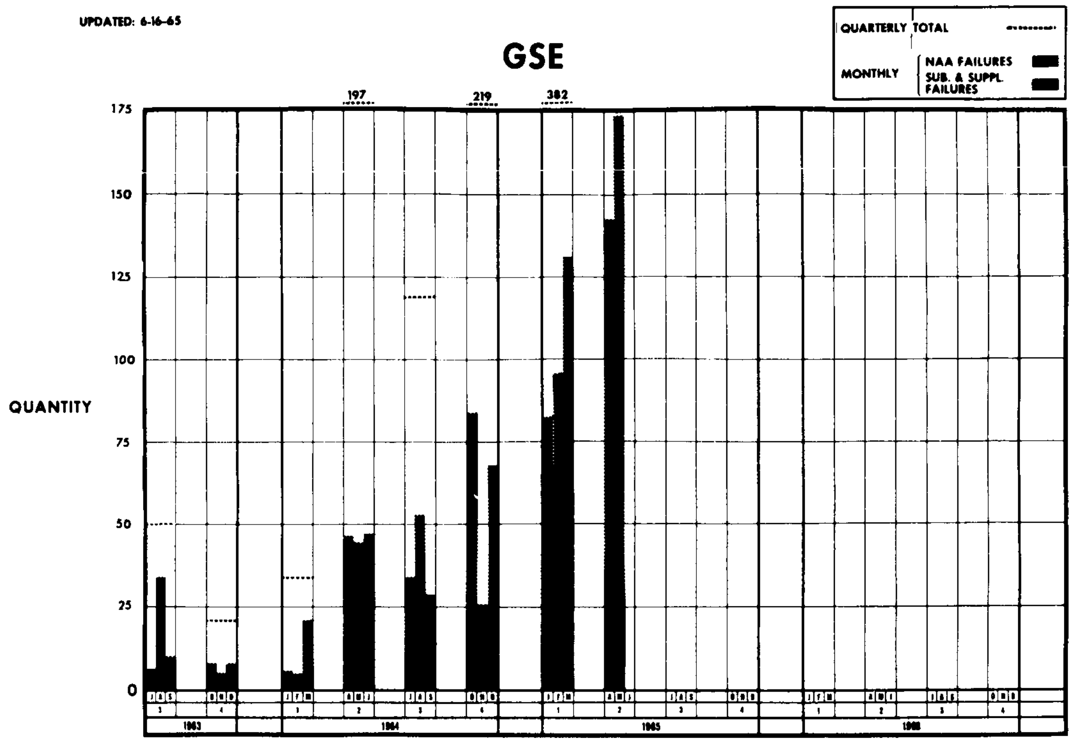


Figure 1-25. Ground Support Equipment Failures

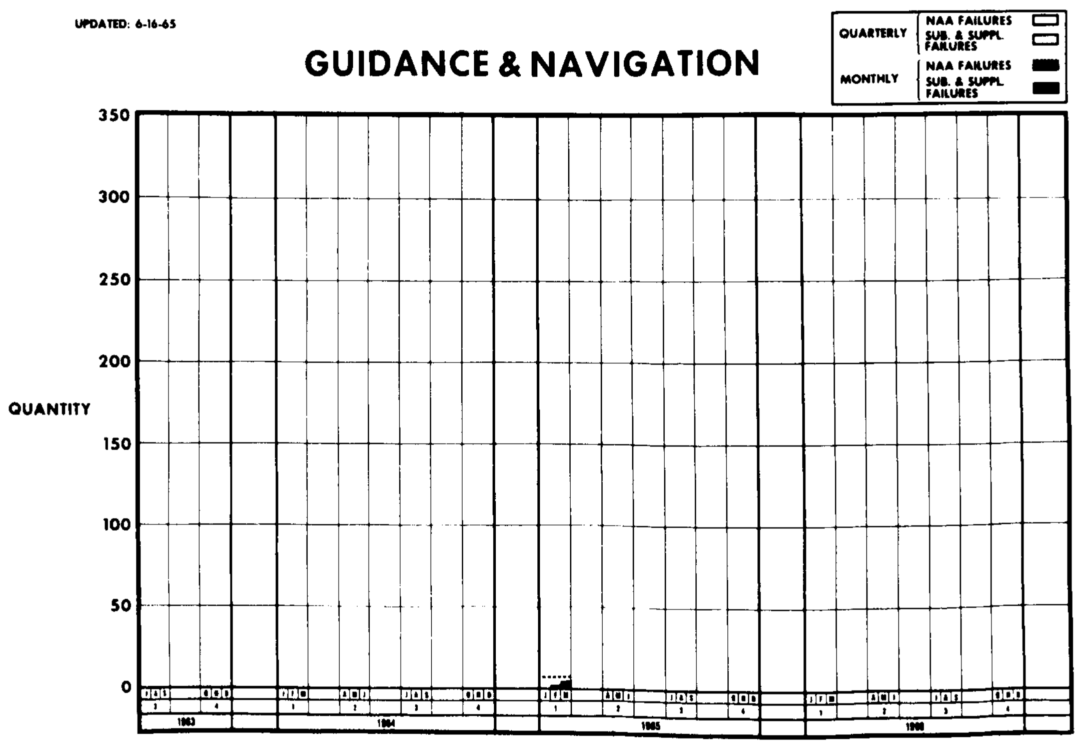


Figure 1-26. Guidance and Navigation Subsystem Failures

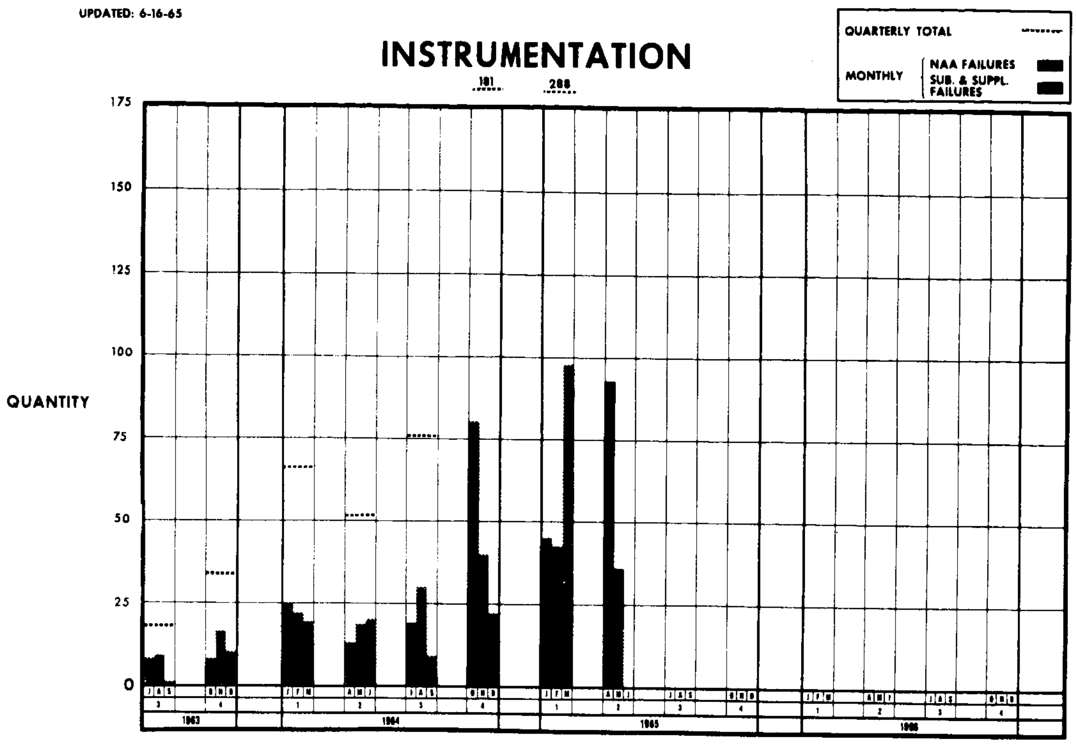


Figure 1-27. Instrumentation Subsystem Failures

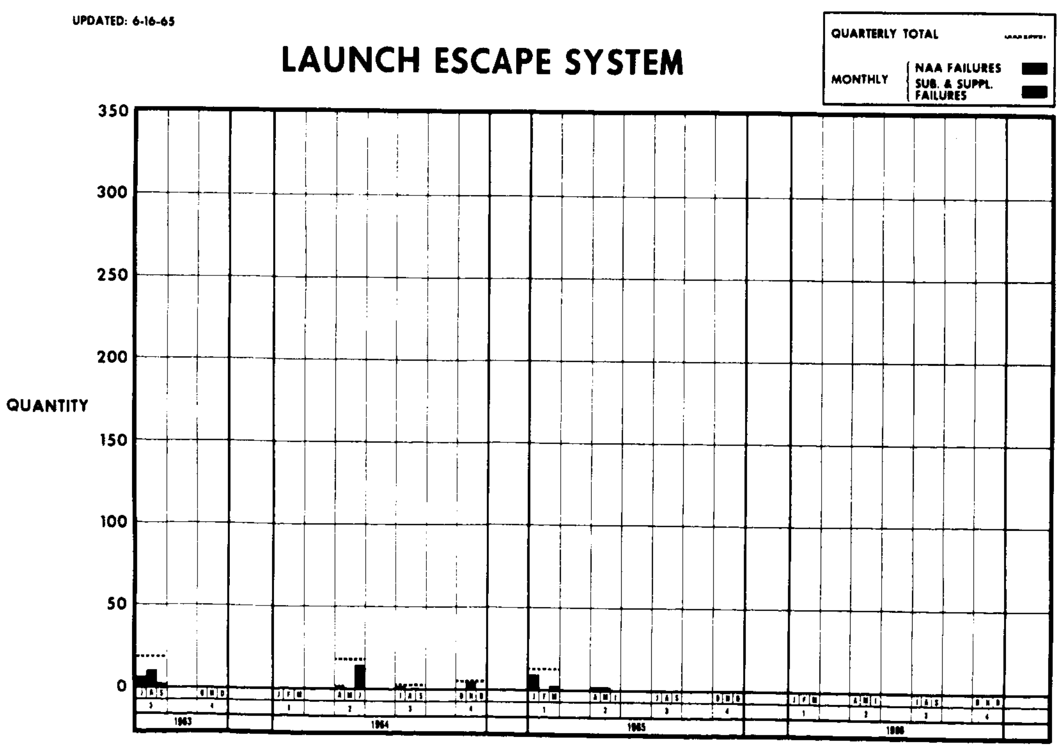


Figure 1-28. Launch Escape Subsystem Failures

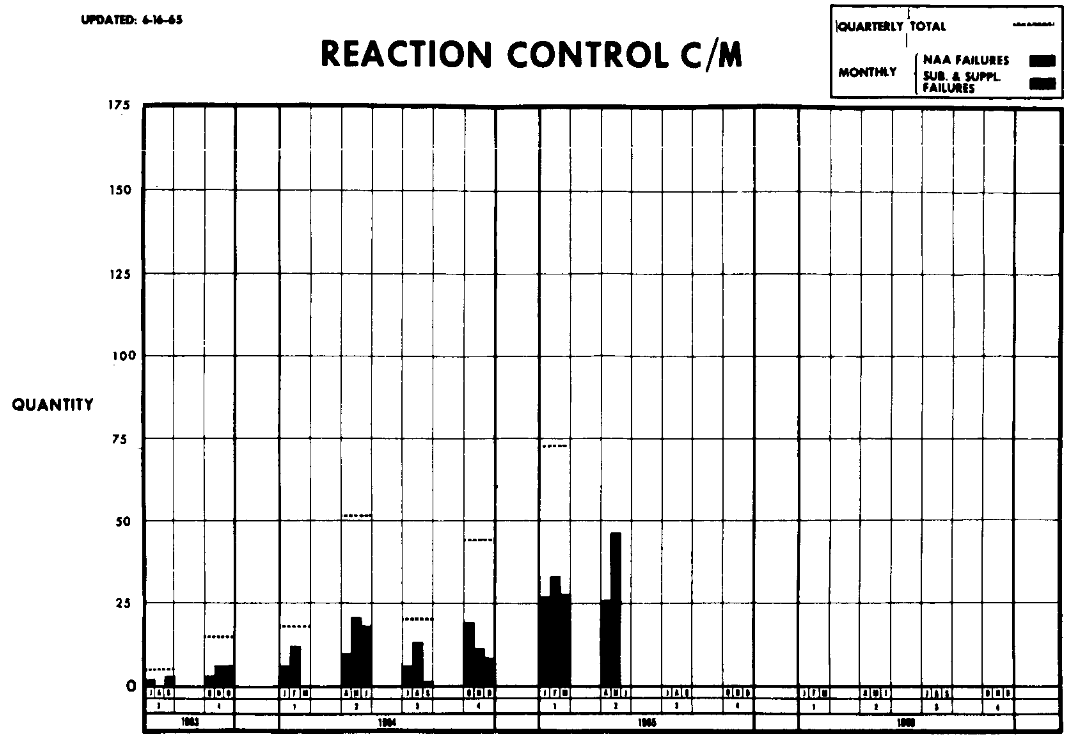


Figure 1-29. Reaction Control Subsystem Failures

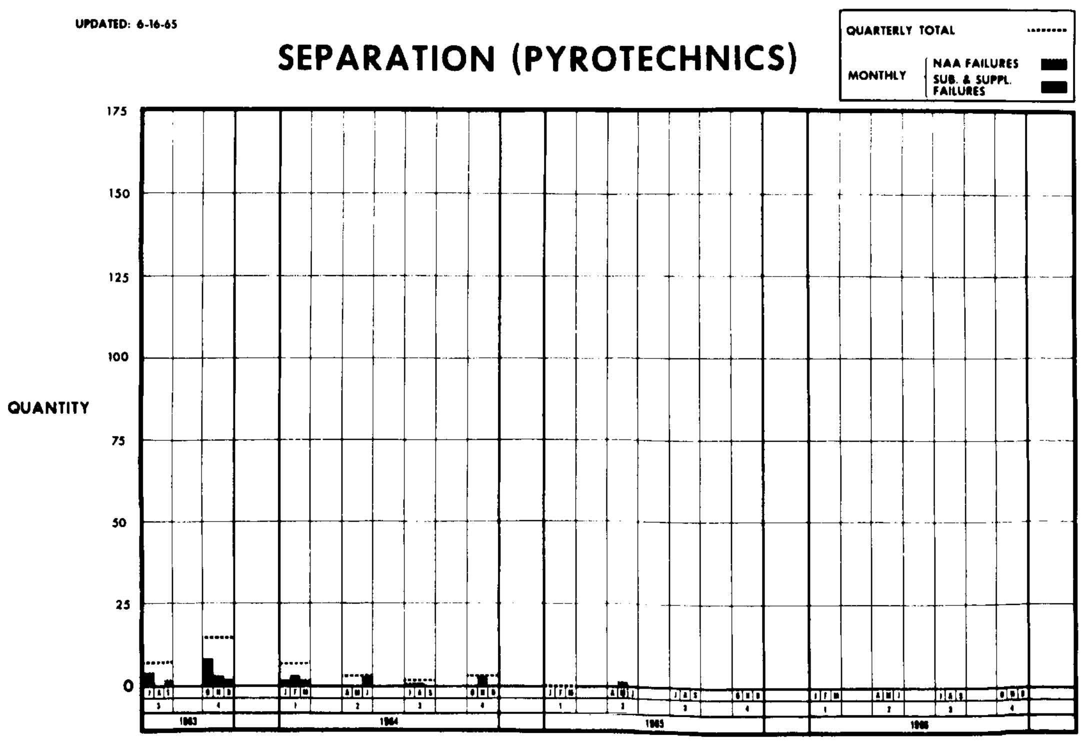


Figure 1-30. Separation Subsystem (Pyrotechnics) Failures

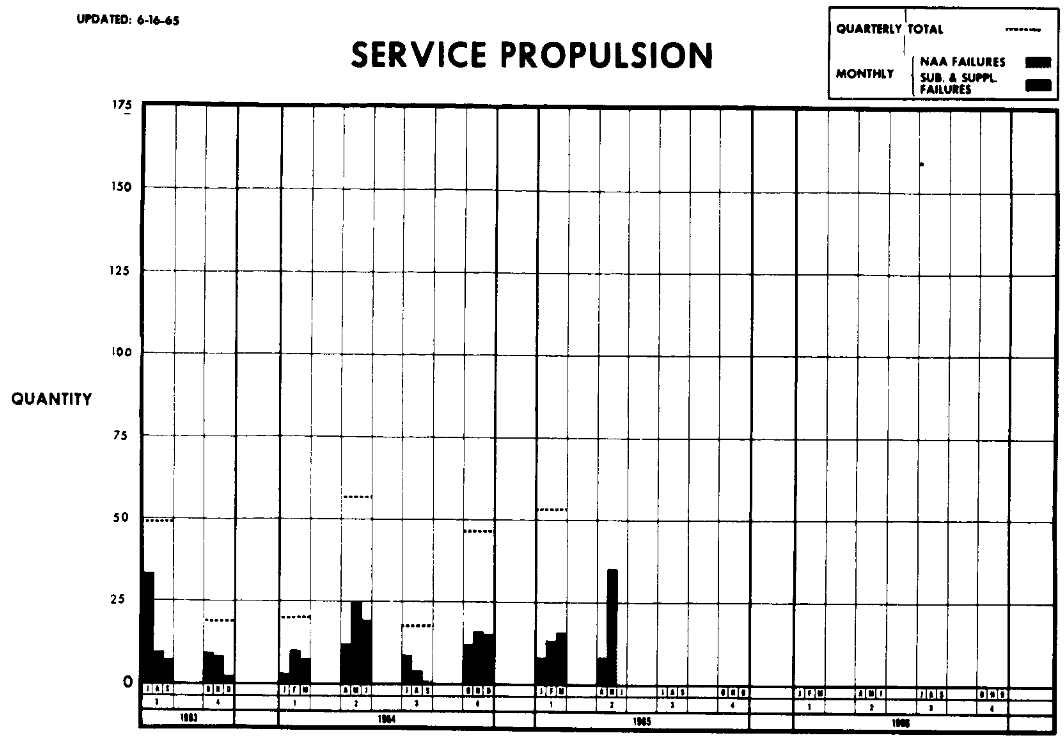


Figure 1-31. Service Propulsion Subsystem Failures

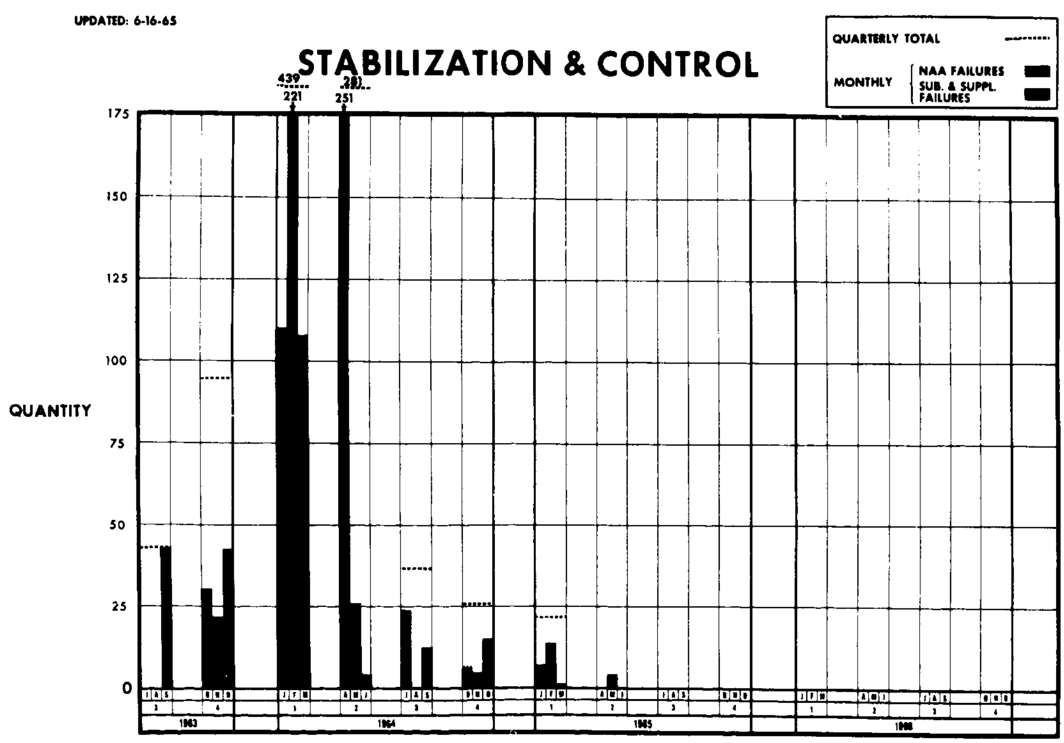


Figure 1-32. Stabilization and Control Subsystem Failures

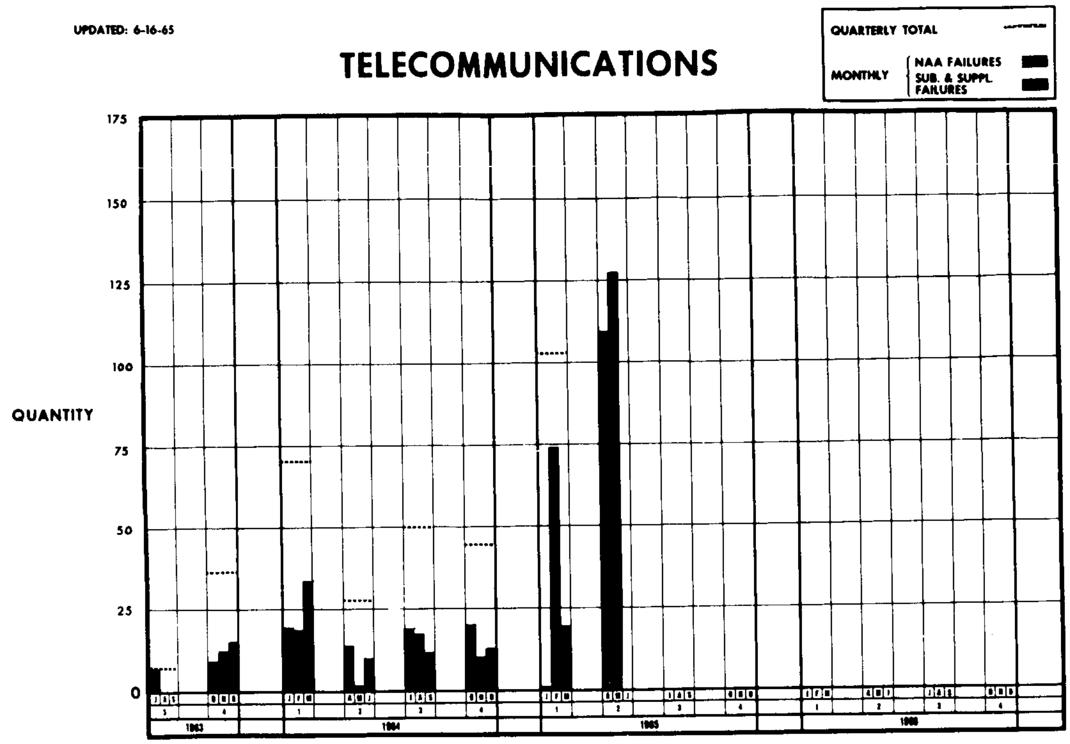


Figure 1-33. Telecommunication Subsystem Failures

1.8 PARTS AND MATERIALS

1.8.1 PARTS MANAGEMENT ACTIVITIES

1.8.1.1 Electronic/Electrical Parts Definitions

During this quarter, the following definitions were established for electronic/electrical parts to provide standardization between S&ID and the hardware manufacturers:

1. Established Reliability (Code PP-1). PP-1 parts conform to a high-reliability specification consisting of reliability and quality control requirements for each part within a specific group. The specification provides requirements for manufacturing process control, in-process inspection, 100-percent screening and acceptance testing, qualification, and failure rates at maximum rated stress conditions not to exceed 1 percent per 1000 hours at a 90-percent confidence level. Proof of qualification may be established by using data from various sources.

   Note

   Code PP-1 parts will be used for all airborne equipments in spacecraft 012 and subsequent vehicles. If PP-1 parts cannot be procured, deviation requests must be submitted to S&ID, Apollo Reliability, using the following definitions as a priority selection.

2. Proven Parts (Code PP-2). PP-2 parts do not provide for the same degree of controls and documented history as PP-1, but are equivalent to PP-1 parts in physical and performance characteristics and source of supply. In general, these parts are MIL-specification quality or equivalent, with added requirements such as 100-percent screening, I&T classification, control of load material, and radiographic inspection.

   Parts that conform to the above definition are considered acceptable only if; (1) PP-1 parts cannot be procured, (2) additional acceptance criteria are invoked, and (3) approval is granted by S&ID.

3. Selected Parts (Code PP-3). PP-3 parts are capable of being qualified for the established reliability or proven categories and are controlled by an acceptable specification (MIL, S&ID, supplier, etc.). This category includes state-of-the-art parts with limited failure rate and qualification testing information.

   Parts that conform to the above definition are considered acceptable only if: (1) PP-1 and PP-2 parts cannot be procured, (2) additional acceptance criteria are invoked, and (3) approval is granted by S&ID.

4. Uncontrolled Parts. Uncontrolled parts are selected from suppliers' catalogs and purchased by suppliers' commercial part numbers without reference to any controlling specification. These may be purchased from part distributors. Generally there is no assurance of qualification.

   Parts that conform to the above definition are considered unacceptable for any spacecraft application. However, if adequate parts in categories PP-1, PP-2 or PP-3 cannot be procured, then uncontrolled parts will be used based on additional acceptance criteria being invoked and approval being granted by S&ID.

1.8.1.2 Preferred Parts List Revision

The S&ID Reliability Preferred Parts List, SID 65-12, revised 15 May 1965 was issued and copies distributed to S&ID, the subcontractor, the supplier, and NASA personnel. The connector, diode, and transistor lists were revised, and an integrated circuits list was added. A great percentage of the parts added are classified as PP-2; however, most of them will be upgraded to the PP-1 classification when the qualification program of the various suppliers is completed; the remainder will be funded for additional testing.

Various subcontractors, such as Honeywell and Collins, were requested to furnish S&ID with their preferred parts list so that a greater number of preferred parts might be covered. The greater coverage will provide minor suppliers with information on availability and source of the subject parts.

1.8.2 SUBCONTRACTOR/SUPPLIER DOCUMENTATION REVIEW

A summary of subcontractor/supplier part specifications and part lists reviewed during this quarter are listed in Table 1-4. Parts included in subcontractor/supplier's lists are added to the Preferred Parts List if the specific definitions are met.

Table 1-4. Parts Documents Review Summary

Subcontractor/Supplier	Specification	List	Parts
Autonetics		1	918
Philco		1	43
Westinghouse	5		5
United Control		1	28
Kearfott		1	15
AVCO		1	16
American Wiancko	16	2	63
Space Science	3	2	39
Microdot		1	42
Control Data Corporation	21	1	39
Giannini	8		8
Total	53	11	1,216

For most of the lists, approvals were withheld pending changes recommended to assure compatibility of the part level with the criticality of its application. Other causes for withholding approval were: (1) lack of sufficient data to show minimum acceptable acceptance and/or qualification; and (2) inadequate definitions of requirements (e.g., design, environmental, etc.) to show if the proposed part is compatible with the application.

1.8.3 PARTS PROBLEM AREAS

1.8.3.1 Connectors

A test program was initiated at S&ID to establish the severity of the coupling ring retention problem on the Cannon connectors (Type PV) during random vibration. Concurrent with this program, agreement has been reached with the manufacturer for a new seat design on the retaining ring as a solution to the retention problems. A random sample was selected from a lot of 100 to be subjected to a series of tests by the manufacturer. The results of the tests will establish the corrective action to be taken.

1.8.3.2 Transistors

The 3N74 transistors procured from Texas Instruments were received from Radiation, Inc., stock to continue the investigation into the open-bond failure reported in the last Quarterly Report. Metallographic examination of the bonds is planned.

An investigation of the failure mode of the gold-to-aluminum wedge bond problem in transistors (General Instrument 2N753) supplied to Radiation, Inc., and Collins Radio (subcontractor), was conducted to ascertain environmental stresses required to duplicate the open-bond failure mode. A comparison of these environmental stresses with design requirements was planned to determine possible overstresses that might occur during a mission. The environmental tests performed did not produce any open bonds similar to those which occurred at Radiation; therefore, no direct comparison was made to determine potential overstresses. However, based on the above results and metallographic examination, the following conclusions on potential failure problems were reached: (1) wide variance of bond strengths, (2) need for more adequate process and quality controls, and (3) evidence of intermetallic growth. The following recommendations were made: (1) screening tests presently employed at Radiation should be continued, and (2) Approval for use in Block II and subsequent equipment should be withheld until evidence is provided that the part supplier has resolved the previously mentioned problems.

1.8.4 PARTS COORDINATION MEETINGS

1.8.4.1 Bell Laboratories

A meeting was held with personnel from Bell Laboratories, consultants for NASA/Houston, to discuss the semiconductor problems on the Apollo Program. The technical interchange that resulted from this meeting (and from subsequent coordination) covered the procedures to be followed during the failure analyses of the 3N74 and 2N753 transistors discussed previously. As a result of this meeting, agreement was reached, and the procedures followed were in consonance with those discussed.

1.8.4.2 NASA Parts Working Group

Two monthly meetings of the NASA Parts Working Group were attended by personnel from NASA, General Electric, Grumman, MIT, A.C. Spark

Plug, and NAA/S&ID. The Working Group is part of the new Apollo parts and materials program which will document (not control) the airborne parts and materials used on the Apollo for future application on other manned space programs.

Meetings scheduled with the Grumman Aircraft Company concerning data exchange at the part level and methods to be used in preferring parts were cancelled because these items are included in the NASA Parts Working Group agenda.

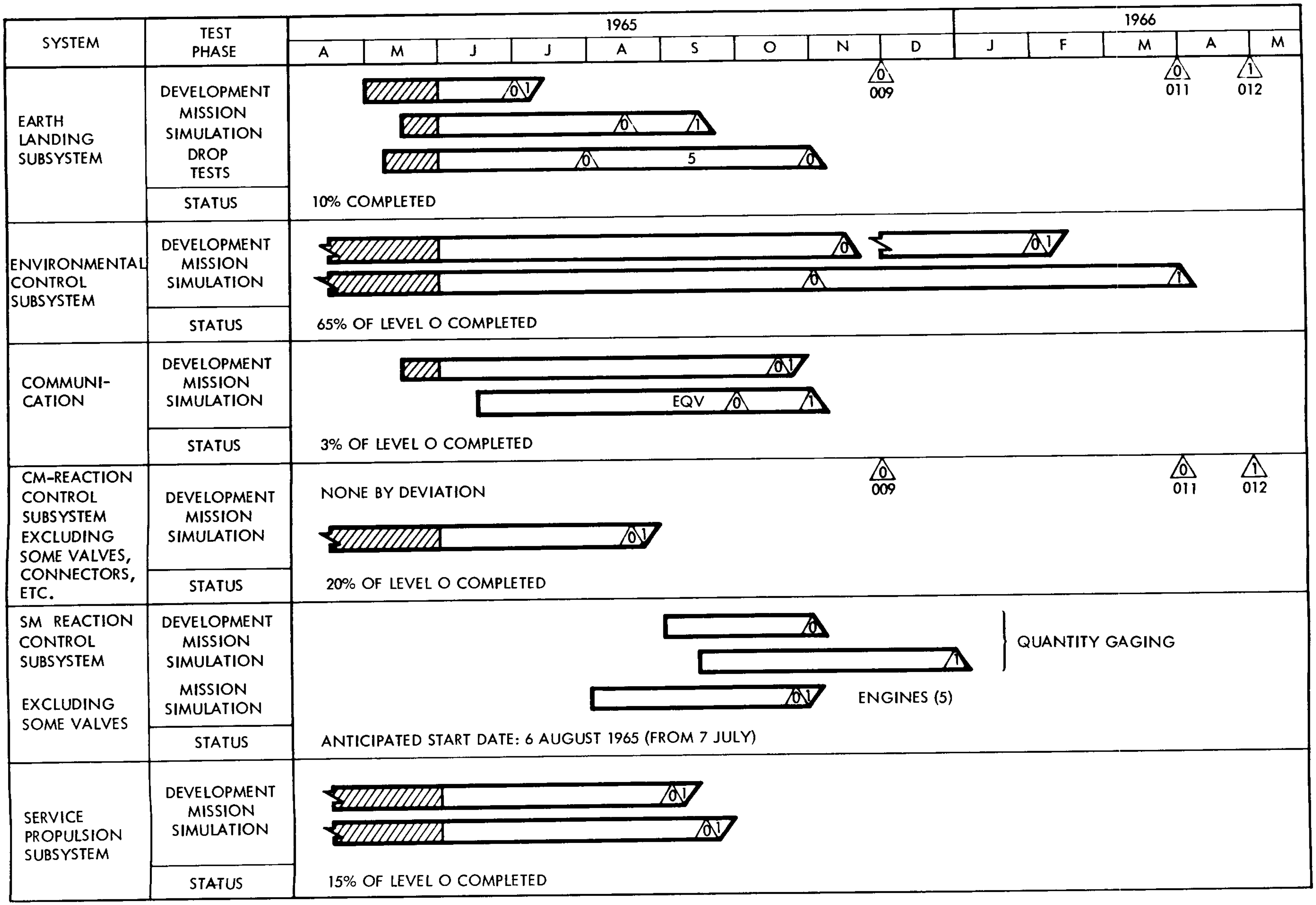


Figure 1-34. Systems Qualification Test Status, Spacecraft 009, 011, and 012 (Sheet 1 of 2)

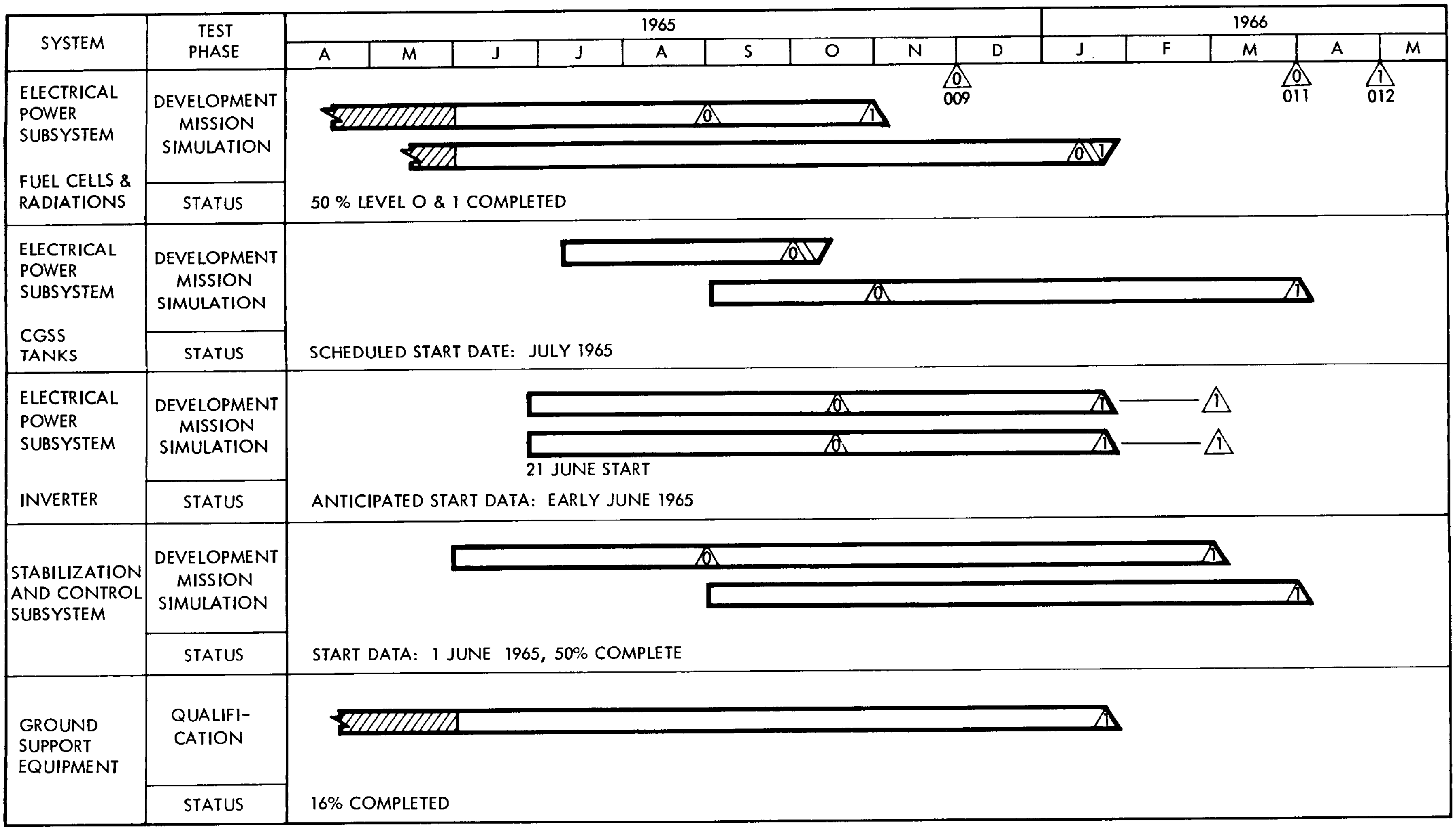


Figure 1-34. Systems Qualification Test Status, Spacecraft 009, 011, and 012 (Sheet 2 of 2)

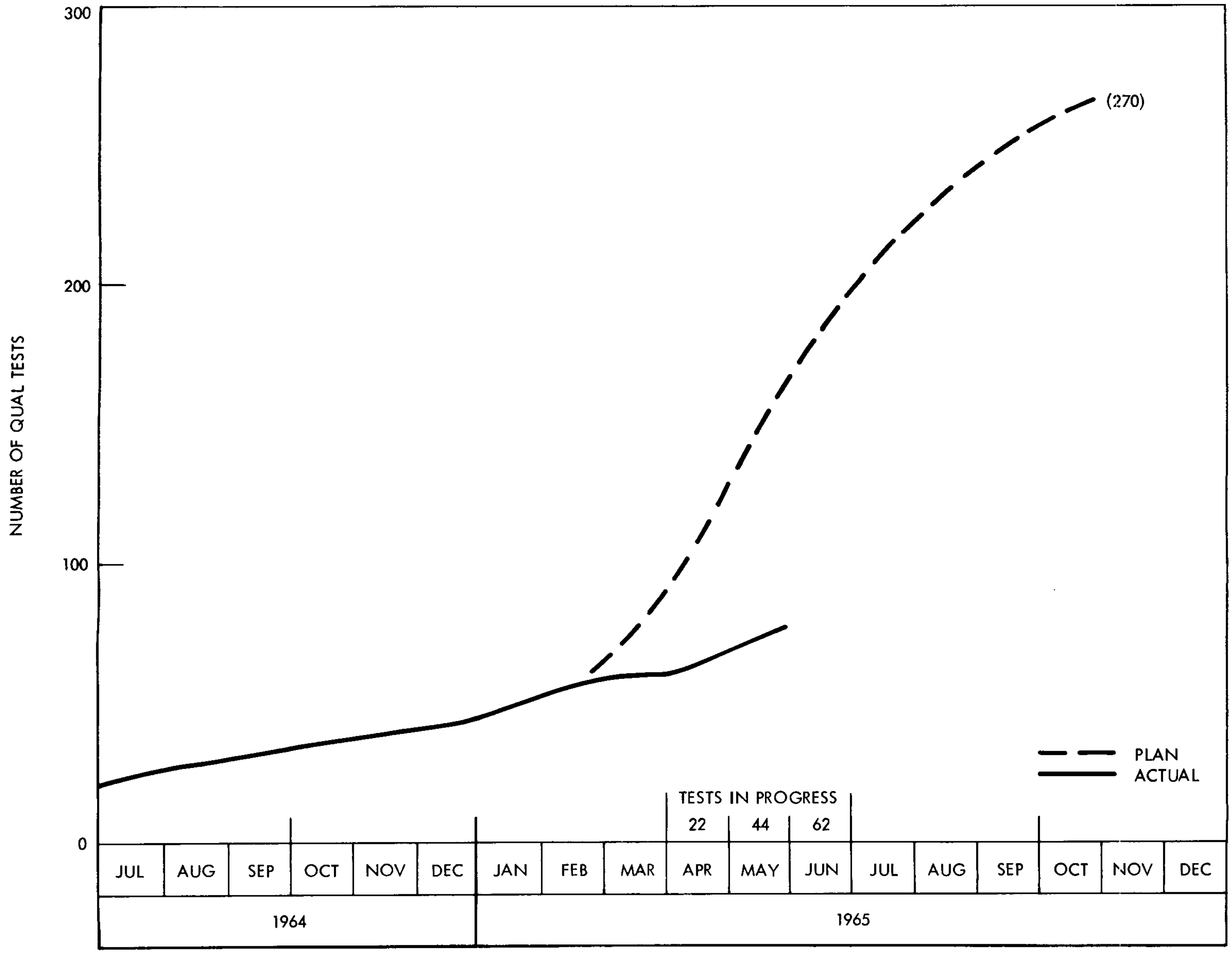


Figure 1-35. Spacecraft 009 Planned Versus Actual Tests in Process

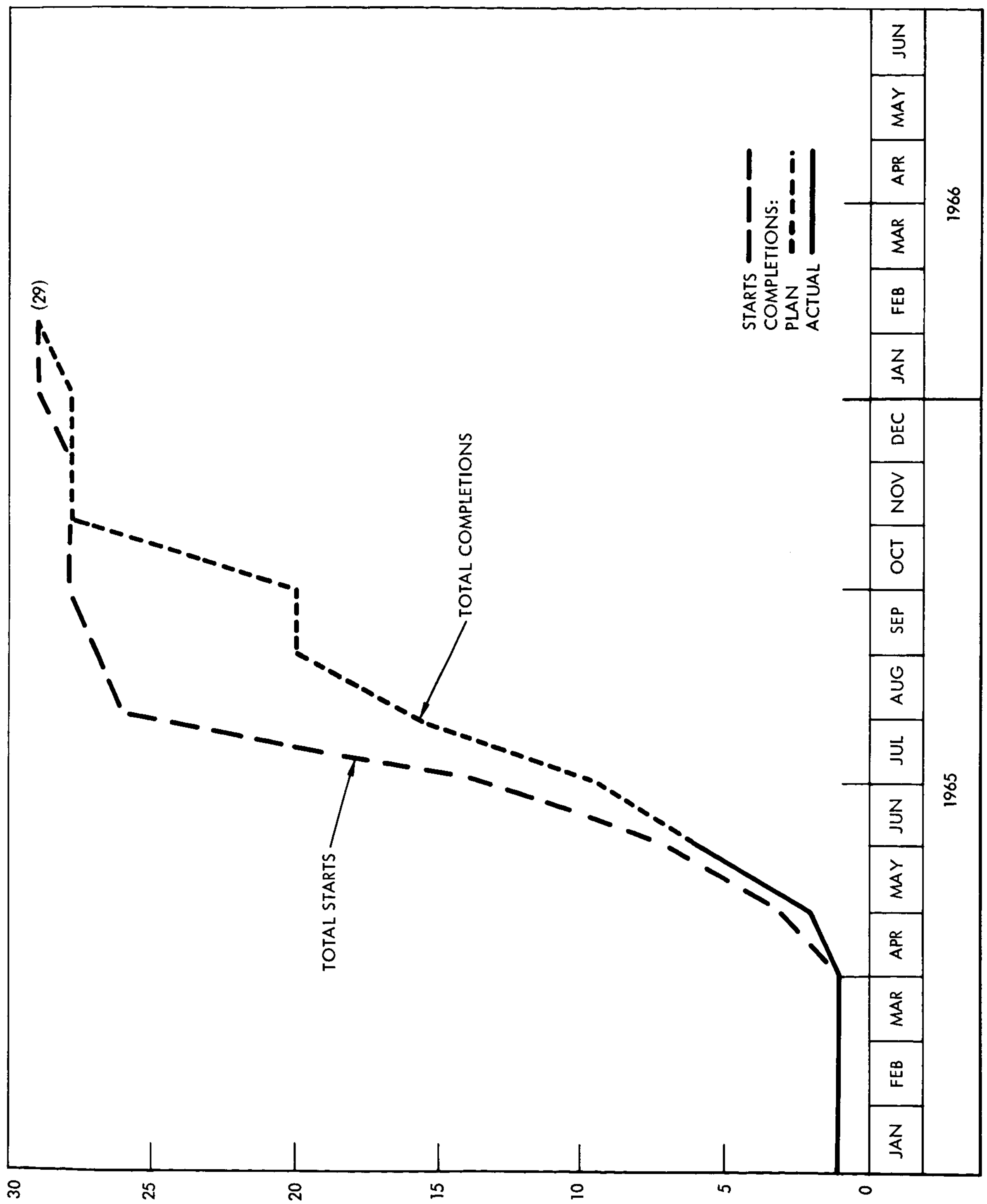


Figure 1-36. GSE Environmental/EMI Qualification Test Status

1.9 TEST PLANNING AND MONITORING

During this reporting period, emphasis was placed on implementing the requirements of the NASA/NAA Test Requirements Report, SID 65-120, which describes the overall test criteria for the CSM, the qualification ground rules, special studies, significant problem areas, and certification test networks for Spacecraft 009, 011, and 012.

The extent and the nature of subcontractor/supplier test monitoring was defined during this reporting period. This was based on subcontractor-supplier, development-design verification test success history and the critical function of the subsystem, assembly, or component. Major test surveillance efforts will be effected for hardware provided by subcontractors, major suppliers, and/or hardware classified as Criticality I or II.

Two procedures were generated, approved, and implemented to provide an internal control and a uniform method for determining the readiness of an item to commence qualification testing and for approving the qualification test program reports. The qualification test start approval procedure delineates the action to be taken prior to the scheduled start of qualification at a subcontractor/supplier or upon a request to start qualification from any NAA testing agency. The qualification report approval procedure delineates the action to be taken upon receipt of a qualification test report and action subsequent to NAA and NASA approval. Each procedure clearly stipulates areas of responsibility, departmental interfaces, and mode of implementation.

The status of subsystems qualification testing is shown in Figure 1-34. Actual versus planned tests in process are shown in Figure 1-35. Figure 1-36 shows the status of GSE environmental-EMI qualification test status.

1.10 INDOCTRINATION AND TRAINING

During this report period, an indoctrination program relative to the Apollo Reliability Plan was developed. This generated a need for additional clarification programs on design analysis, design review, failure reporting, and corrective action. The material developed for use at S&ID, Downey, will be considered for presentation to Florida Reliability personnel. Cost effectiveness will determine the media to be employed. The major effort will be directed toward the identification of Apollo reliability problem areas, reporting procedures, data acquisition, and support of flight readiness.

Seven Apollo personnel attended reliability-oriented S&ID technical courses during this reporting period. (See Table 1-5.)

The in-house Apollo reliability audit program was redirected and formalized to reflect the principles delineated in the NASA Manual for Auditing Contractor Plans and Performance, the tasks defined in MDS-8, and the program being implemented at the supplier level. The audit program was designed to indicate the administrative and business systems employed by Apollo Reliability and the technical progress achieved. The audit program, as revised, will be implemented in July.

The Apollo committee for quality improvement (CQI), formed during the last reporting period, is functioning as planned. Manufacturing problem areas are discussed, and corrective action is assigned to responsible groups. Such problem areas as bonding, welding, transducer sealing, fastener installation, valve leakages, damaged parts, etc., have been discussed with corrective action assigned and initiated. This function, in conjunction with failure reporting and trend charting, provides visibility into those problem areas conducive to reliability degradation.

During this reporting period, 36 copies of supplier brochures and 23 reliability kinescopes were forwarded to Apollo suppliers upon request.

Table 1-5. Technical Courses

Course	No. of Presentations	Total Student Hours
Computer Methods of Analysis	11*	49.5
Symbolic Logic	4*	24.0
Total	15	73.5
*Course completed		

1.11 DOCUMENTATION

Reliability reports issued during this report period include the following:

Reliability Quarterly Status Report, SID 62-557-13, 1 May 1965

S&ID Preferred Parts List, SID 65-12, revised 15 May 1965

Reliability Program Plan, SID 62-203, Addendum 5 May 1965

2.0 MECHANICAL SUBSYSTEMS ANALYSIS

2.1 CREW PROVISIONS

2.1.1 SUMMARY

Final failure mode effect analyses (FMEA's) for the waste management subsystem (WMS) and preliminary FMEA's for the crew couch and strut assembly were completed. WMS system development tests are in progress. The majority of crew systems component qualification tests were rescheduled for next quarter because qualifiable hardware was unavailable and because the testing agency required more time to prepare the detailed test procedures. The crew couch and strut assemblies qualification testing programs are proceeding on schedule.

2.1.2 ANALYSIS

2.1.2.1 Waste Management Subsystem

Final FMEA's for the WMS were completed for Block I manned flights. The revised system logic reported in SID 62-557-12 was updated, but no significant changes were required and the previously published logic diagrams are adequate.

A single-point failure summary for the WMS on Spacecraft 012 was completed. The only mission essential, Criticality II component on the system is the urine dump line. Loss of this line by rupture would result in loss of cabin pressure, which would subsequently require an abort.

2.1.2.2 Crew Systems

Logic diagrams for crew systems were limited to those components that interface with other Apollo systems. Components having independent functions were reviewed for effect on crew safety and mission success, and appear on the crew systems single-point failure summary. Logic diagrams for Block I components appearing in SID 62-557-13, Table 2-1, were completed and are shown in Figures 2-1 through 2-3. (Sight assembly and oxygen recharge hose assembly are Block II components.)

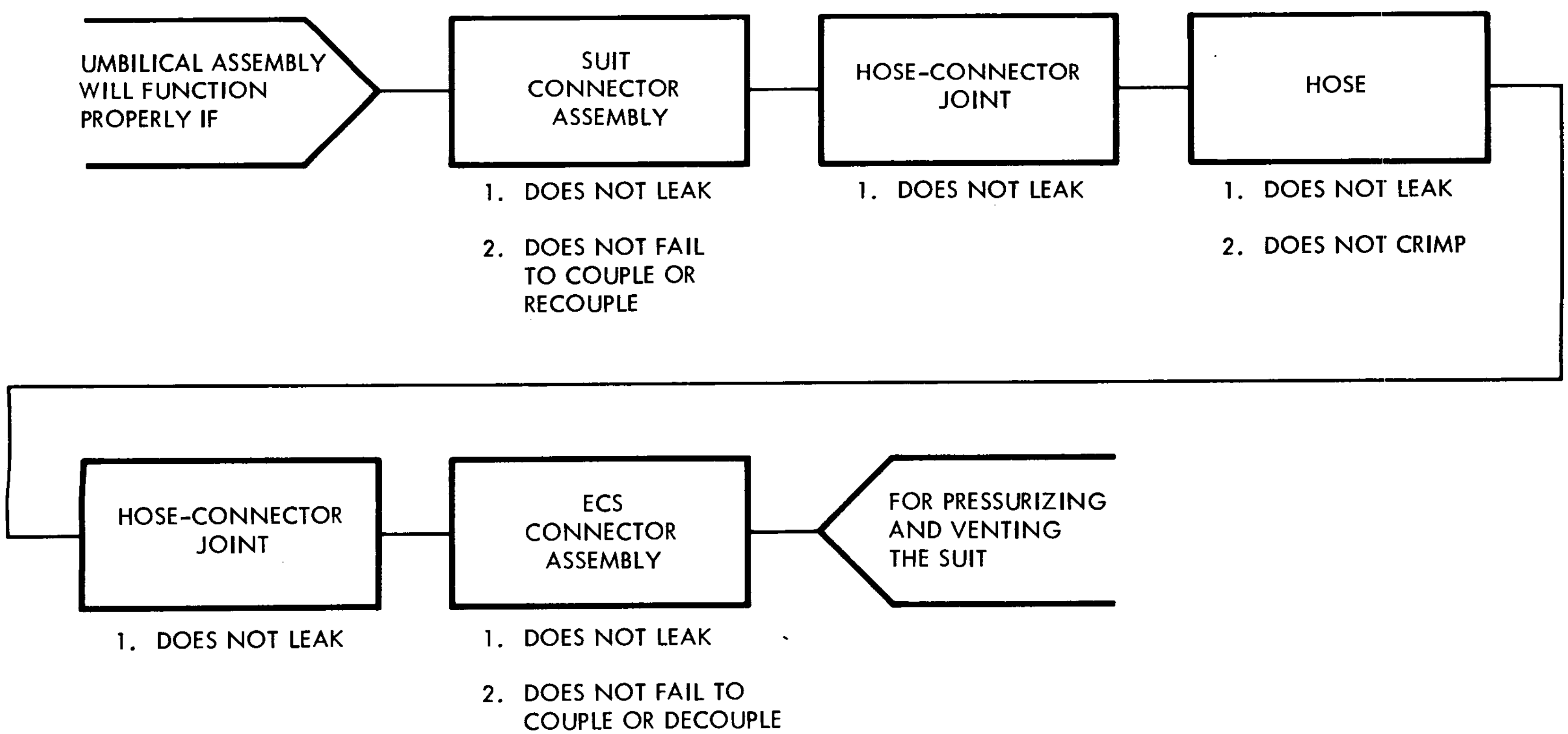


Figure 2-1. Oxygen Umbilical Assembly, Mission Success Logic Diagram

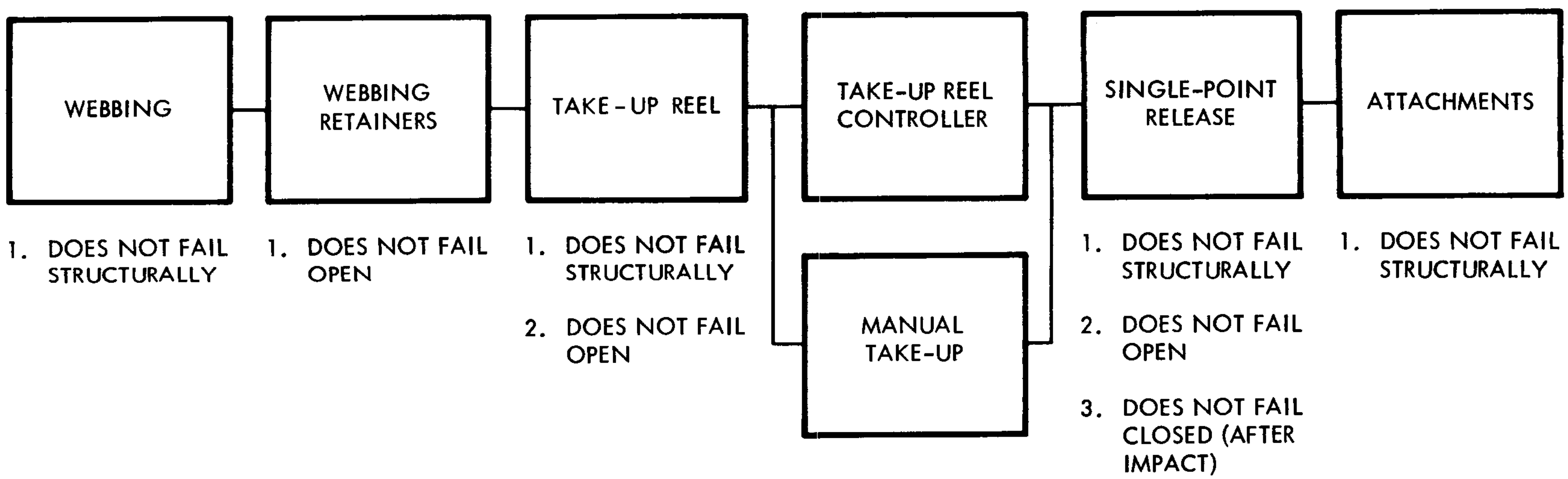


Figure 2-2. Harness Assembly, Crew Safety Logic Diagram

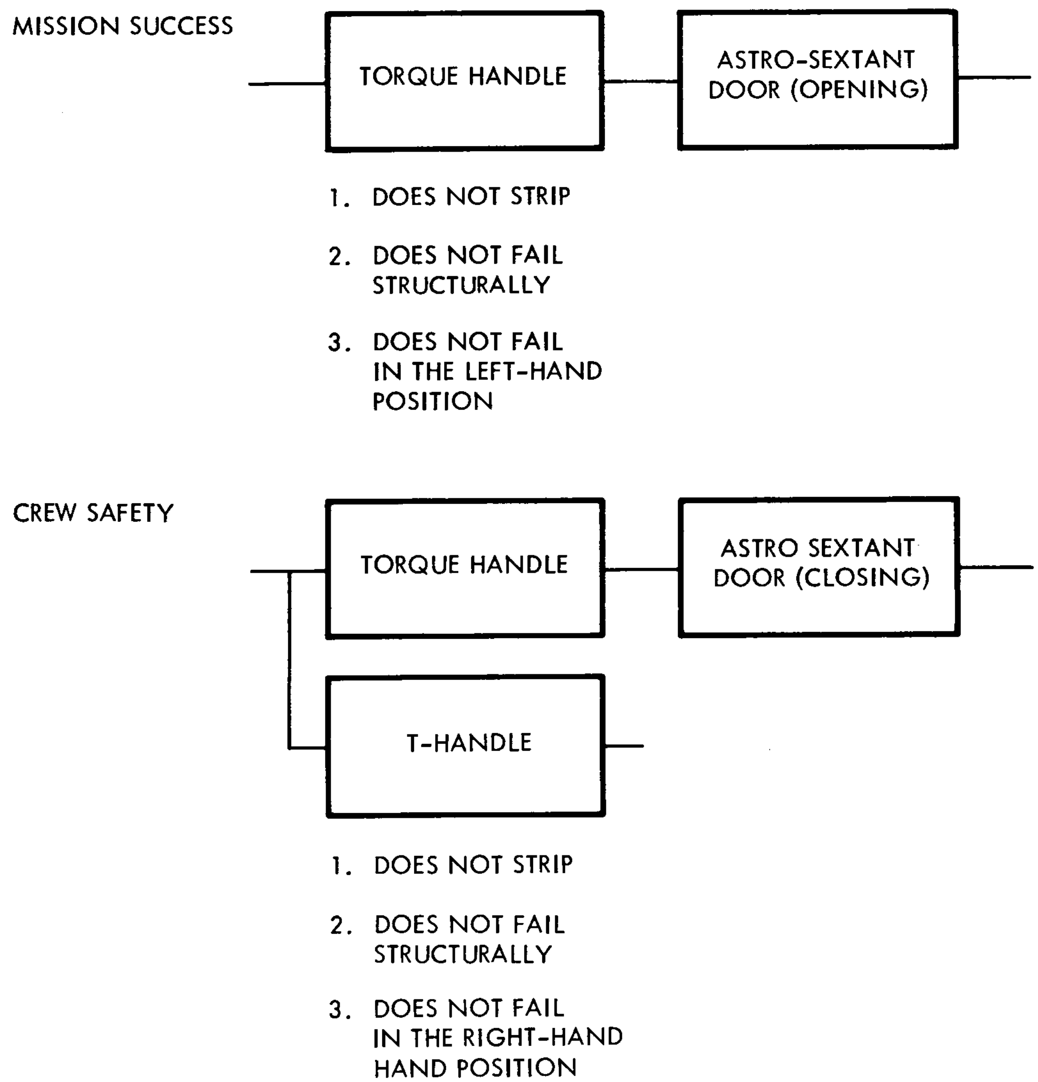


Figure 2-3. Torque Handle Tool Set Logic Diagram

2.1.2.3 Crew Couch

Preliminary FMEA's were prepared for the struts and major assemblies of the crew couch. Final analyses will investigate each assembly and the effect of failures on mission or crew safety at the component level. Although the strut FMEA's were made for Spacecraft 012, they may be utilized for earlier unmanned flights since the only major difference is that the unmanned versions have the lockouts removed on the X-X struts.

2.1.3 TEST PROGRAM

2.1.3.1 Waste Management Subsystem

The WMS system tests are being set up and calibrated at NAA. Phase I of these developmental tests is in process, and Phase II, consisting of design verification tests, is scheduled to start in July 1965.

Three WMS system components have completed qualification: backup valve, waste management control unit, and urine disposal lock. The delay in starting qualification on the vacuum cleaner was due to completing open items on contract rather than to hardware development. Although a minor, out-of-tolerance pressure-drop reading was encountered during the blower voltage variation test, it was considered insignificant and qualification was allowed to continue.

The material investigation for the ventilating check valve discussed in SID 62-557-13 was completed by the supplier, and silicon rubber was selected to fabricate the valve flapper. The porosity encountered previously was caused by contamination in the mix and mold. A new vendor for molding the flapper was obtained, and various quality control measures were instituted to improve the flapper quality. After successful completion of a series of development tests, including a 10,000-cycle life test, the supplier restarted qualification. The one subsequent failure was traced to a faulty O-ring, which was independent of previous failures. Additional inspection requirements were imposed on the O-ring and qualification was restarted.

2.1.3.2 Crew Systems

Preparation continued on qualification test requirements for S&ID-fabricated components, and qualification process specifications on 12 of the 18 components were released. Development testing on the zero-g sandals and oxygen hose, two procured components for crew systems, is complete, but qualification of the sandals was delayed until an adhesive suitable for space environment was obtained and tested. The restraint harness assembly and the crewman's optical alignment sight assembly are continuing developmental testing.

Crew systems components to be released for bid next quarter include the oxygen hose assembly for Block II, recharge hose assembly for Block II, outer fecal bag, and the mirror assembly.

2.1.3.3 Crew Couch and Strut Assemblies

There is no significant change in the test status for the crew couch and strut assemblies from that reported in SID 62-557-13 except that qualification of the lock-out release solenoid was delayed until next quarter.

2.1.4 PLANNED ACTIVITIES

Detailed FMEA's for the crew couch are planned for completion during the next report period. Block I FMEA's will be finalized and Block II FMEA's prepared, if required. Continued support, including monitoring of critical tests, will be furnished for the qualification of S&ID-fabricated crew systems hardware.

2.2 EARTH LANDING

2.2.1 SUMMARY

Problems encountered with the reefing line cutters and main chute disconnect are expected to be resolved by redesign. Mortars and cartridges are undergoing changes for correction of specific deficiencies, and qualification test failures of the sea dye marker are under investigation.

2.2.2 ANALYSIS

The logic diagram for the Block I earth landing subsystem (ELS), Figure 2-1 of SID 62-557-13, was revised to reflect the new main chute disconnect and deletion of the inertia switch unit from Spacecraft 011. Figure 2-4 presents only that portion of the logic that was affected by the changes. The revised single-point failure summary is shown in Table 2-1.

Table 2-1. ELS Single-point Failure Summary

Component	Potential Failure Mode	Criticality	Occurrence Probability
Relay K2 (Sequencer)	Premature transfer	I	Unknown
Relay K3 (Sequencer)	Premature transfer	I	Unknown
Relay K4 (Sequencer)	Fails to transfer	I	Unknown
Main disconnect	Either of two units fails to sever harness	I	Unknown
Drogue attach	Fails in tension	I	Low
Confluence fitting	Fails in tension	I	Low

2.2.3 TEST PROGRAM

Table 2-2 lists results of the drop tests conducted at El Centro during this report period.

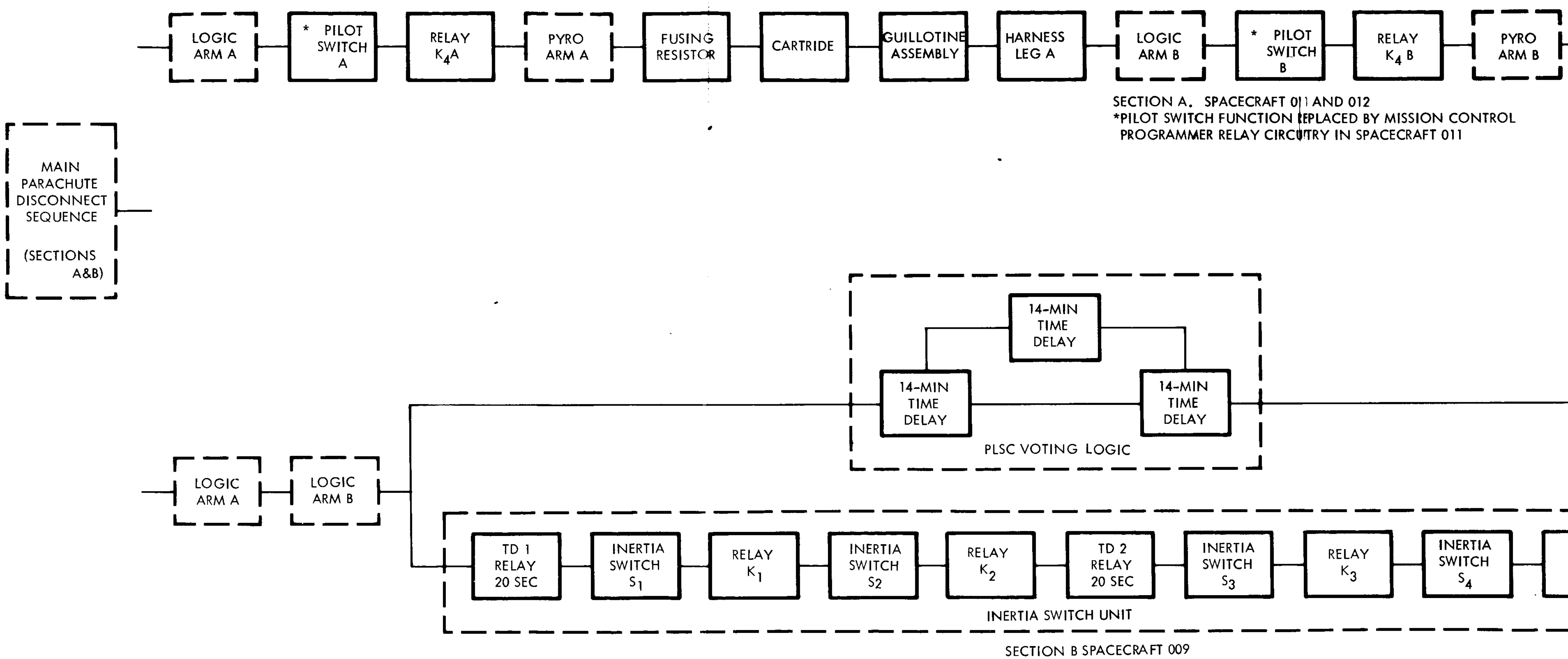
Table 2-2. ELS Drop Tests

Drop Test	Date	Purpose	Test Results
60-1	6 May 1965	Constraint on Boilerplate 22 Block I configuration	Successful
62-2	3 June 1965	Qualification test	A main chute was found to have two suspension lines tied together with a bite-tie cord. An error in packing was suspected. In addition, three reefing line cutters failed to fire: one cutter was on each of two drogues and the third was on one main chute. These cutters were of obsolete design and not considered part of the qualification test. The test was otherwise successful.

2.2.4 PROBLEM AREAS

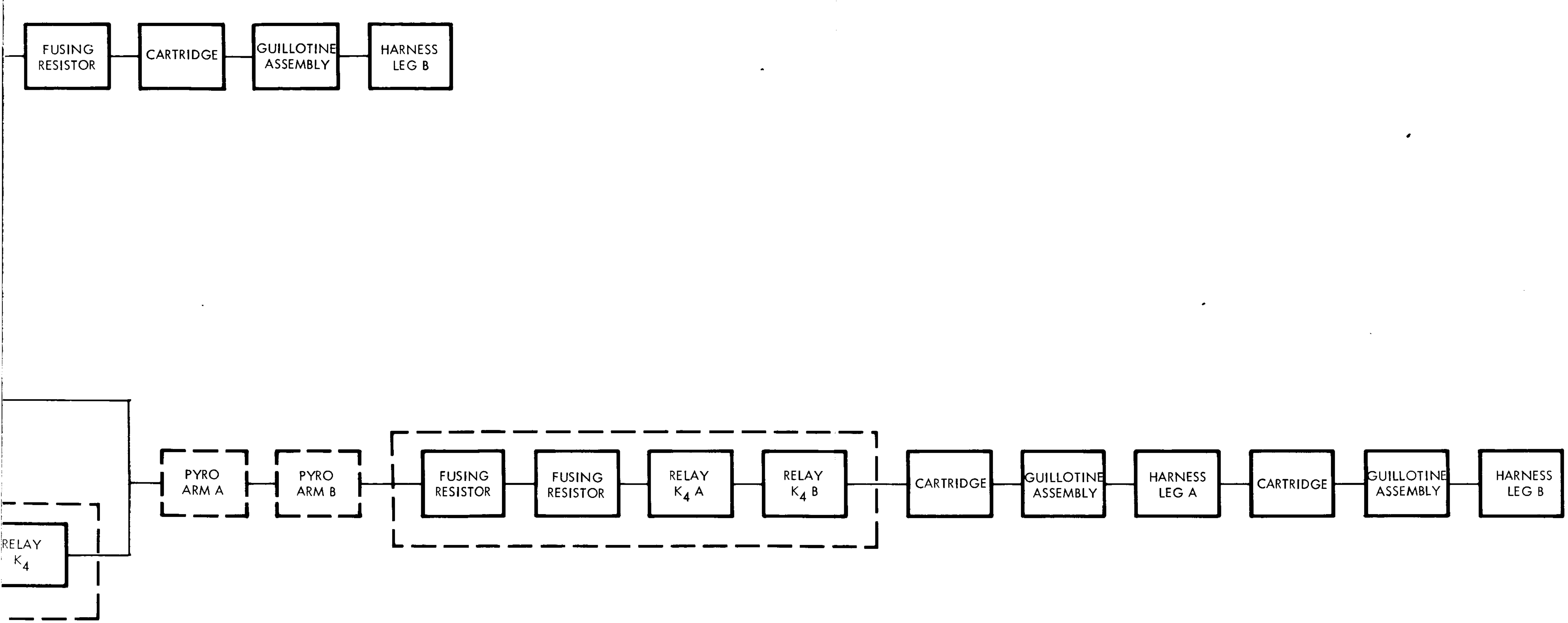
2.2.4.1 Mortars

Because of test failures of the drogue cartridge with the 0006 initiator, a decision was made by Northrop to use a flame diverter between the initiator output and booster charge in the cartridges. In addition, the drogue mortar will incorporate a new breech design that precludes direct impingement of one cartridge output on the other by offsetting the cartridge bosses. Excessively high drogue mortar reaction loads resulting from the faster response time of the 0006 initiator were experienced during development testing. To overcome the high loads, a slower burning powder mix will be tested in the drogue mortar cartridge, and a smaller main charge will be used in the pilot cartridge.



LOGIC ARM A
* PILOT SWITCH A
RELAY K_4A
PYRO ARM A
FUSING RESISTOR
CARTRIDE
GUILLOTINE ASSEMBLY
HARNESS LEG A
LOGIC ARM B
* PILOT SWITCH B
RELAY K_4 B
PYRO ARM B
SECTION A. SPACECRAFT 011 AND 012
*PILOT SWITCH FUNCTION REPLACED BY MISSION CONTROL PROGRAMMER RELAY CIRCUITRY IN SPACECRAFT 011
MAIN PARACHUTE DISCONNECT SEQUENCE
(SECTIONS A&B)
14-MIN TIME DELAY
14-MIN TIME DELAY
14-MIN TIME DELAY
PLSC VOTING LOGIC
LOGIC ARM A
LOGIC ARM B
TD 1 RELAY 20 SEC
INERTIA SWITCH S_1
RELAY K_1
INERTIA SWITCH S_2
RELAY K_2
TD 2 RELAY 20 SEC
INERTIA SWITCH S_3
RELAY K_3
INERTIA SWITCH S_4
INERTIA SWITCH UNIT
SECTION B SPACECRAFT 009

FOLD-OUT #1



FOLD-OUT #2

Figure 2-4. ELS Logic Diagram (Revised Portion of Figure 2-1, SID 62-557-13)

2.2.4.2 Main Parachute Disconnect

As a result of unsuccessful underwater operation of the shaped-charge disconnect, the design of a new guillotine-type cutter was completed. The new cutter is now undergoing development tests.

2.2.4.3 Reefing Line Cutters

A new reefing line cutter is in process of development to overcome the problems encountered in old cutters.

2.2.4.4 Sea Dye Markers

Two of four dye markers failed the 12-hour qualification test in the Salton Sea by exhibiting a total life of six to eight hours. The cause of failure is under investigation. A third marker was lost during recovery and its total life could not be determined; the fourth marker successfully completed the 12-hour requirement.

2.2.5 PLANNED ACTIVITIES

Qualification and development test surveillance and investigation of test failures will continue.

2.3 ELECTRICAL POWER*

2.3.1 SUMMARY

Principal analysis effort during this period was directed towards the preparation of preliminary vehicle reliability logic diagrams, single-point failure summaries, and the FMEA.

The electrical power subsystem (EPS) was reviewed to eliminate all uncontrolled parts and components scheduled for flight vehicles. As a result of an upgrading investigation, the a-c and d-c sensing units are being redesigned, and preliminary steps were taken to redesign the motor switches.

The battery charger qualification test program was extended by the addition of two new tests mutually agreed upon by NASA and S&ID. Corrective action was taken by the pyrotechnic battery supplier on the six failed pyro batteries, which will be requalified to determine if the corrective action was adequate.

The qualification program for the majority of connectors is nearing completion. Many of these connectors had been previously qualified except for the corrosive contaminants (oxygen-humidity) test recently added to the requirements. No significant problems were reported in any of these qualification tests to date.

Development of the static inverter and the 40 ampere-hour batteries is almost complete, and qualification testing on both components is expected to start within three months.

Action was taken by Autonetics and S&ID to resolve problems of commercial parts and contaminated relays being used in the master events sequence controller and service module jettison controller.

Qualification testing of the cryogenic gas storage subsystem (CGSS) was initiated at Beech Aircraft, and qualification tests were completed on the oxygen and hydrogen disconnects. Also, a design review of the Block II configuration was conducted. Corrective action measures concerning audit deficiencies were received from Beech.

*This section includes information on the cryogenic gas storage subsystem, previously contained in a separate section.

Two fuel cell modules which had begun qualification testing during the report period failed at different times and for different reasons. A reliability program audit was conducted at Pratt & Whitney Aircraft (P&W), and a mode FMEA (PWA-2540) was received and reviewed.

2.3.2 ANALYSIS

2.3.2.1 Logic Diagrams

The EPS preliminary logic diagrams were completed for all test and flight vehicles prior to Spacecraft 012, and updating is in process. Logic diagrams of the CGSS for Spacecraft 002, 008 and 011 are scheduled for completion during the next report period.

2.3.2.2 Failure Mode and Effects Analysis

Preliminary FMEA's for the EPS unmanned configuration are complete, and FMEA's for manned vehicles are being generated. Completion of FMEA's on the CGSS scheduled for this report period has been delayed because of possible new failure modes evident during the development program at Beech.

FMEA's on the fuel cells were contained in the Pratt & Whitney Progress Report for December, PWA-2540. This report, which also contained failure rates and logic diagrams, was reviewed and found to be completely acceptable. No duplication of this effort will be performed by S&ID.

2.3.3 PROBLEM AREAS

2.3.3.1 Kinetics Parts Upgrading

An extensive effort is underway to discontinue the use of all uncontrolled parts and components for Spacecraft 012 and subsequent vehicles. The a-c and d-c sensing units are being redesigned at the S&ID Compton Facility to incorporate controlled parts. A parts list from Kinetics Corporation was reviewed for reliability controls. Kinetics has used various uncontrolled electronic components in their motorized switch sensing units. The changeover from uncontrolled parts to high-reliability (or equivalent) parts is being accomplished prior to the first manned Block I flight. A criticality effects study is being made on all motor switches.

2.3.3.2 Fuel Cell Failures

Two fuel cell modules failed during qualification testing. The first, P650717, had an open circuit type failure on 20 March 1965 after 101.75 hours of the 366-hour vacuum endurance portion of the test. After an investigation it was concluded that the primary cause of failure was excessive plugging of the oxygen inlet tube resulting from abnormal contamination of the oxygen gas supply system. Trichlorethance was found as a contaminant in the oxygen gas during acceptance testing, and it was the joint decision of S&ID, NASA, and P&W to rebuild and retest this fuel cell. P&W initiated procedural controls as corrective action to safeguard against contamination on future production hardware. Disposition of the test is awaiting all analysis and corrective action documentation and NASA acceptance.

The second fuel cell, P650718, failed on 13 April 1965 after 407.06 hours of load time when the unit was placed on open circuit for electrolyte dryout following successful completion of Vibration Test No. 2. During the dryout period, powerplant malfunction was indicated by reactant flow and a rising stack surface temperature. Analysis attributed the failure to dendritic shorting in the cell stack portion of the module. P&W recommended that this unit be accepted as having completed qualification testing because the load time was beyond mission life. NASA concurrence is required for this disposition.

2.3.3.3 Oxygen and Hydrogen Disconnects

The oxygen and hydrogen disconnects for the CGSS that failed qualification, as discussed in the 13th Quarterly, successfully passed all phases of qualification testing.

2.3.3.4 Special Applications Connector

The dual-shore rubber insert on the special applications connector (MC 414-0233) has demonstrated inability to retain contact pins when subjected to pressures lower than the specified minimum. A recommended change in insert material to the silicon material that was tested and qualified on the general purpose connector (MC 414-0365) is under consideration.

2.3.3.5 Connector Coupling Sleeve

Two connector coupling sleeves (ME 414-0106) separated from the connector shell while the cables were being mated to a checkout box, and the problem was attributed to improper seating of the retaining ring during manufacturing assembly. An investigation was initiated of all similar connectors mounted in Spacecraft 009 and of all procedures in the ITT/Cannon facility relative to this connector.

As a corrective action, the supplier initiated a coupling torque test on every connector in stock, and connectors already installed in Spacecraft 009 were isolated and tested for proper ring retention. The supplier stated that a redesign of the retaining ring was underway. S&ID directed the supplier to stop work on all connectors until the redesign retaining ring was incorporated.

2.3.3.6 Time Delay Modules

A meeting was held at Parko Electronics Company to investigate their part sources and procedures for screening components. Parko manufactures time-delay modules used in the master events sequence controller and service module jettison controller, which are the heart of the sequencing system. Time delays control the choice and sequence of functions, such as arming and ignition necessary for initiation and termination of events during vehicle operation.

The electronic parts used in the Parko timers are uncontrolled, off-the-shelf commercial parts purchased from various suppliers. Also, Parko uses a capacitor in the timing circuitry that has been proscribed by NASA from all Apollo systems (NASA letter No. 10662MA, dated 27 August 1964) because of two failure modes: (1) incomplete lead-to-electrode bonding of the inner electrode, and (2) cracked ceramic rods. Parko stated that they did not know which of the timers delivered to Autonetics contained the outlawed Aerovox Cerafil capacitor, Type MC80.

During a tour of the Parko facility, it was found that it is a common practice to file resistor and capacitor bodies that extend out too far on the printed circuit board to make them fit into the can used as a protective covering. Furthermore, there are no NASA-trained soldering technicians to solder all the intricate connections in the delicate timing circuitry. It is apparent that these conditions are not suitable for the Apollo program. Therefore, the following plan of action was recommended.

1. All parts used in the Parko timers will be replaced with high reliability parts similar to those called out in the S&ID Preferred Parts Manual, SID 65-12. Established reliability Code PP-1 must be used.

2. The Parko timers already received by Autonetics for use with the master events sequence controller will not be used in manned spacecraft.

3. An immediate investigation will be made by Autonetics of Parko timers to establish which of the timers already received contain MC80 Aerovox Cerafil capacitors proscribed by NASA. These time delays will not be used in any sequencer intended for flight usage.

4. Autonetics will require Parko to use NASA-trained soldering technicians.

5. All Parko time-delay relays will be given a seal leakage test.

6. The practice of filing resistor and capacitor bodies to fit the protective can covering will cease.

7. Parko will establish an identification and traceability system.

Apollo Reliability also recommended that the reliability demonstration test on the 20 Parko time-delay relays at Autonetics that contain commercial, off-the-shelf parts be terminated since a reliability demonstration using commercial parts is illogical. The results of such a demonstration, if successful, would prove only that the commercial parts being tested had a certain failure rate, but would not provide assurance that all Parko timers used in the sequencing system had the same failure rate. This is due to the fact that there is no uniformity of product with commercial parts and, in addition, the manufacturing processes used by Parko appear to be questionable.

2.3.3.7 Relay Contamination

A meeting was held between Autonetics and S&ID Reliability and Engineering personnel to establish a plan of action for resolving the problem of contamination in Babcock relays found during special tests at Autonetics. The Babcock relays are used in the master events sequence controller and the service module jettison controller to control the choice and sequence of functions, such as arming and ignition necessary for initiation and termination of events during vehicle operation. The Babcock relays are also used in the mission control programmer for Spacecraft 009 and in the control programmer. The following plan of action evolved from the meeting:

1. Autonetics will implement immediately a 14-point program that will ensure that relays procured in the future will be equivalent to high reliability items. This program is to be closely coordinated with Babcock.

2. Autonetics will immediately investigate screening techniques that will reject the contaminated relays already received and installed in the master events sequence controller, service module jettison controller, and control programmer.

3. Autonetics will inform S&ID of the impact on the schedule.

4. S&ID will investigate the use of Babcock relays in other applications.

2.3.3.8 Static Inverter

The development program for the redesigned static inverter, Model -004, is still in process. The major problems associated with the existing design, Model -001, are excessive electromagnetic interference radiation, excessive acoustic noise generation, and hot spots discovered during thermal evaluation tests. Model -004 will incorporate circuit layout changes and a new connector to eliminate the electromagnetic interference problem. Redesign of the octadic transformer, using 6.5 percent silicon-iron core material and isolating it in a shielded container, is expected to reduce the acoustic noise to within specification limits. The thermal problem was eliminated by redesign of the controlled current feedback transformer (CCFT), and the transients generated in the circuit by the old transformer were eliminated by changing the CCFT coupling method. Under high-temperature, high-vacuum conditions, the transients excited the power transistors. This caused increased gain and resulted in excessive temperature rise of the unit. The corrective action was incorporated on all Model -0001 units.

Minimum airworthiness tests for Model -0001 units are scheduled to begin in July 1965, but full qualification tests on the Model -004 units cannot be scheduled until the development program is completed.

2.3.4 TEST PROGRAM

2.3.4.1 Battery Charger (ME 461-0002)

As a result of meetings between NAA and NASA, two new tests have been added to the battery charger qualification test program: high-temperature vibration and high-temperature vacuum. Qualification testing is scheduled to be completed on the battery charger in July 1965. To date, there have been no qualification test failures on this unit.

2.3.4.2 Pyrotechnic Battery (ME 461-0007)

As a result of the six pyro battery failures that occurred during qualification testing, four additional redesigned pyro batteries will be qualified. Two batteries will be subjected to a 36-day activated stand test, and the remaining two batteries will be subjected to an acceleration test.

2.3.4.3 General-Purpose Connector (MC 414-0365)

The general-purpose connector was tested to the corrosive contaminants (oxygen-humidity) tests of MC 999-0050A, and the test report was received and approved. A new electrolysis nickel plating was instituted, and for this reason, two sets of connectors will be subjected to the corrosion tests and the corrosive contaminants test of MC 414-0365A. Completion and approval of these tests will constitute complete qualification status for the general-purpose connector.

2.3.4.4 Rectangular Connector (MC 414-0148)

Qualification testing of the rectangular connector was completed and the test report approved.

2.3.4.5 Bulkhead Feedthrough (MC 414-0164)

Qualification testing of the bulkhead feedthrough is complete except for the corrosive contaminants (oxygen-humidity) tests of MC 999-0050A. The test samples will be potted at NAA/S&ID and tested at the supplier's test facility.

2.3.4.6 Launch Escape Tower Umbilical (MC 414-0067)

Qualification testing of the launch escape tower umbilical was restarted when the connector was redesigned to include new inserts and new plating. Testing was completed in May 1965, but the test reports have not yet been approved.

2.3.4.7 Special-Purpose Connector (MC 414-0061)

The Hughes special-purpose connector started qualification testing on 17 May 1965. Two pins could not be removed during the maintenance aging test, and the supplier's representative stated that this was due presumably to the pins being bent during insertion. Hughes recommended additional instructions in the correct technique of pin insertion.

The qualification test is being conducted at the Hughes test facility except for specimens which were potted at S&ID and which are being qualification tested at the Engineering Development Laboratory, S&ID, Downey. To date, no serious problems have been encountered.

2.3.4.8 Subminiature Connector, MC 414-0409

Qualification testing of the subminiature connector started on 17 May 1965. Having developed the connector prior to contract negotiations date, Deutsch was ready to start qualification tests upon acceptance of their proposal. To date, no failures have been reported.

2.3.4.9 Overcurrent, Reverse-Current Switch (ME 452-0038)

Electromagnetic interference testing, which was not performed until the units were redesigned to include additional filter components, is the only remaining test of the qualification program for the overcurrent, reverse-current switch.

2.3.4.10 Overcurrent, Relay Switch (ME 452-0055)

Testing of the overcurrent relay switch was withheld indefinitely pending resolution of the trip time and EMI failures. Environmental tests, originally planned to be met through similarity to the ME 452-0038 switch, are currently being considered for inclusion in the present qualification program.

2.3.4.11 Motorized Relay Switch (ME 452-0045)

The ME 452-0045-0004 and the ME 452-0045-0005 configurations of the motorized relay switch were qualified and the report approved. The -0001, -0002, and -0003 versions are not considered flightworthy for manned space flights.

2.3.4.12 Storage Battery (Eagle-Picher)

The 40-ampere-hour capacity storage battery is in the final stages of development testing. Environmental and cycling tests on individual cells have been completed.

Three prototype units of 20 cells have been submitted to development tests and have demonstrated the ability to meet dynamic tests. The final configuration of the battery was tentatively agreed upon pending successful completion of the remaining development tests.

2.3.4.13 Cryogenic Gas Storage

Recent problems at Beech Aircraft Corporation (BAC), Boulder Division, including titanium weld failures and vacuum acquisition, resulted in serious schedule delays. To compensate for these delays, a meeting was held at BAC to initiate a plan of action to implement the qualification test program on the component level rather than the system level as originally planned. This allowed BAC to start the qualification test program on units in-house on 24 May 1965. The first units designated for qualification were the oxygen and hydrogen signal conditioner which had successfully passed end-item acceptance tests. The expected completion of Phase A (design proof tests) is 15 October 1965.

2.3.5 SUBCONTRACTOR MANAGEMENT

2.3.5.1 Reliability Program Audits

A reliability program audit was conducted at Pratt & Whitney, manufacturer of the fuel cells, on 26 and 27 April 1965. An audit report was completed and is currently being transmitted to Pratt & Whitney with instructions to correct deficient areas.

As a result of a reliability audit, comments on deficient areas transmitted to BAC were answered and corrective action implementation was ensured. The date for full implementation of corrective action on all deficient areas is 15 June 1965.

2.3.5.2 Design Review, Block II

A design review of the CGSS was held at BAC on 26 through 29 May 1965. Although no improvement is shown in the apportionment for Block II design because of limited data, there is an overall improvement in design and better performance characteristics. S&ID requested that BAC Reliability perform additional analysis on the Block II design. The design, even though it differs somewhat from Block I and R&D concepts, is an improvement and should meet the specification requirements for Block II, Procurement Specification MC 901-0685.

2.3.6 PLANNED ACTIVITIES

During the next report period, tests will continue on the sequential events control subsystem hardware. Information derived from these tests will be analyzed and incorporated into the system math model for periodic updating. High reliability relays and time delays will be procured for use in the master events sequence controller and the service module jettison controller for manned spacecraft.

All corrective action reports on titanium weld failures and vacuum acquisition problems will be reviewed prior to qualification tests of the oxygen and hydrogen tanks. Monitoring will be accomplished on critical qualification tests at Beech Aircraft, Boulder Division.

The following analyses will be accomplished in support of specific spacecraft:

1. Preliminary logic for the EPS radiators for Spacecraft 001, 011, and subsequent vehicles.
2. Preliminary logic for the CGSS on Spacecraft 014 and final CGSS logic on Spacecraft 002, 008, and 011.

3. Preliminary single-point failure summaries for CGSS on Spacecraft 001 and 008.

4. Updated FMEA's on the EPS radiators for Spacecraft 001, 011, and subsequent vehicles.

5. Updated FMEA's on the CGSS for Spacecraft 011 and 012.

2.4 ENVIRONMENTAL CONTROL

2.4.1 SUMMARY

The environmental control subsystem (ECS) qualification test program was revised in accordance with direction by the NAA and NASA Qualification Review Board.

Part I of the Spacecraft 009 Development Engineering Inspection (DEI) meeting for the ECS was supported, and the following analyses were completed: logic diagrams for Spacecraft 011 and 012, single-point failure summary for Spacecraft 012, and the FMEA for Spacecraft 011. In addition, a special reliability study on a proposed Block II ECS water-glycol circuit was completed.

2.4.2 ANALYSIS

2.4.2.1 Design Engineering Inspection

Part I of the Spacecraft 009 DEI was held on 20 through 22 April 1965. During the DEI an engineering thermal analysis was reviewed which indicated that the inverter and attitude gyro accelerometer package modules would exceed the 150 F operating temperature limits under the following worst case condition: failure of the GSE water-glycol cooling supply to the vehicle 30 minutes prior to launch, followed by failure of the ECS water-glycol pump at launch. As a result of these conditions, the inverter and the AGAP temperatures would exceed the 150 F operating temperature limits by 3 or 4 degrees due to lack of water-glycol cooling at the end of the Spacecraft 009 flight. These temperatures were not considered significant enough to preclude the attainment of mission objectives and therefore the ECS water-glycol circuit was classified as nonessential for the Spacecraft 009 mission.

2.4.2.2 Logic Diagrams

Preliminary logic diagrams for the Spacecraft 011 and 012 ECS were completed except for the failure modes which are to be added at the scheduled update milestone. The subcontracts logic diagrams for the ECS Block I configuration are being evaluated.

2.4.2.3 Single-Point Failure Summary

The preliminary single-point failure summary for the Spacecraft 012 was completed. The principal failure modes that could require a mission abort are glycol leakage and loss of function in the water-glycol circuit. There are no known single failures in the Spacecraft 012 ECS that could cause loss of the crew.

2.4.2.4 Failure Mode Effect Analysis

The preliminary FMEA for Spacecraft 011 ECS was completed and showed the principal failure modes to be leakage and loss of function for the water-glycol and water supply components.

The effect of water glycol leakage, depending on the amount, would be the eventual overheating of the electronic modules due to the lack of coolant flow through the coldplates. Loss of function of certain water-glycol and water supply components would also allow overheating of the electronics, but over a greater time span than a leakage-type failure.

2.4.2.5 Special Study, Block II ECS Water Glycol Circuit

Design Engineering requested that Apollo Reliability prepare a critique of the proposed Block II ECS water-glycol circuit, and provide reliability philosophy and reliability design criteria regarding this circuit. Major recommendations from the completed study are summarized as follows;

1. Mission success coldplate redundancy was not recommended (crew safety redundancy is to be provided)

2. The suit heat exchanger, cabin heat exchanger, and the space radiators should be included in the secondary (crew safety) water-glycol circuit

3. Sizing of the space radiators and the associated temperature controls should be designed to carry all the anticipated mission heat loads without benefit of any evaporator (water boiling) requirements

4. The ECS radiators should be redundant to provide a safe abort cooling mode that is independent of evaporator (water boiling) modes of cooling.

2.4.3 PROBLEM AREAS

A review of the qualification test failures indicates that a significant number of subcontractor failure reports are still open. Out of 56 failures, 35 failures have open status, some of which are 6 months old. The subcontractor has been directed to improve the failure reporting system and to decrease the lag time between failure and submittal of their corrective action report.

2.4.4 TEST PROGRAM

2.4.4.1 High-Q Abort Vibration Requirements

The subcontractor was directed to incorporate the high-q abort vibration level into the Group I qualification tests. All components that have not been vibration tested will be subjected to this 2-1/2-minute high-q abort level after the 12-1/2-minute atmosphere flight vibration level test. S&ID will review all components that have already been subjected to the Group I vibration tests to determine which components will have to be retested to the high-q abort level. Each component will be functionally checked out to its design requirements after the atmosphere vibration level testing. S&ID will also establish the operational requirements for all components which are required to function after aborting. The subcontractor was directed to delete all high-q abort vibration testing from the Goup III qualification tests.

2.4.4.2 Qualification Program Redirection

In compliance with SID 65-250, both in-house and the subcontractor's qualification programs are being revised to comply with SID 65-120, NASA/NAA Qualification Requirements Report.

2.4.4.3 Qualification Testing

A total of 67 different components comprise the complete ECS Group I test program, and 36 have passed the Group I qualification tests, 14 of these during the report period.

The Group III qualification test program is continuing on an accelerated basis to meet the DD-250 schedule date for Spacecraft 012.

2.4.4.4 Development Testing

The suit heat exchanger cooling test is continuing, with special emphasis on the cyclic accumulator operation after all the water is removed from the gas.

The glycol evaporator tests are continuing, with emphasis on the automatic water control. Many problems were encountered with the automatic water control, including the wetness control, location of the wetness sensor, use of a super-heated grid, and potential flooding.

The CO_2 element testing on the 50 percent bypass-type is continuing to give delta pressure problems. The LiOH dusting problem during vibration has been solved by using a new filter and padding materials.

The silicone fluid used in the coolant subsystem is being tested to check its compatibility with each component.

2.4.4.5 Breadboard Test

The first phase of the breadboard test is continuing on an accelerated program. Problems were encountered in the cabin pressure relief valve (810400-1-1), with the ambient sense port poppet valves sticking to the seats. Once the poppet valve breaks open, however, the valve operates within specification. This component appears to have a relatively short shelf life. The problem is being investigated.

2.4.5 SUBCONTRACTOR MANAGEMENT

The reliability audit report was formally transmitted to AiResearch on 14 April 1965, with instructions to correct the deficiencies noted. A reply was requested regarding the action taken by AiResearch in each of the deficient areas.

An Apollo Reliability representative was assigned to AiResearch on a part time basis to monitor the qualification test program, to evaluate test equipment and techniques, and to assist in failure analyses and procedures.

2.4.6 PLANNED ACTIVITIES

The following analyses will be completed during the next reporting period:

1. Preliminary FMEA for Spacecraft 012, 014, and 017
2. Preliminary logic diagrams for Spacecraft 014 and 017
3. Single-point failure summaries for Spacecraft 011, 014, and 017.

2.5 HEAT SHIELD

2.5.1 SUMMARY

Avco reliability assessment of the ablative heat shield subsystem with respect to meeting the 600 F backface temperature criteria was evaluated. Cracks caused by stress concentrations on the inner face sheet of the Spacecraft 009 command module heat shield are being investigated. Avco is developing methods for improving radiographic detection of ablator defects.

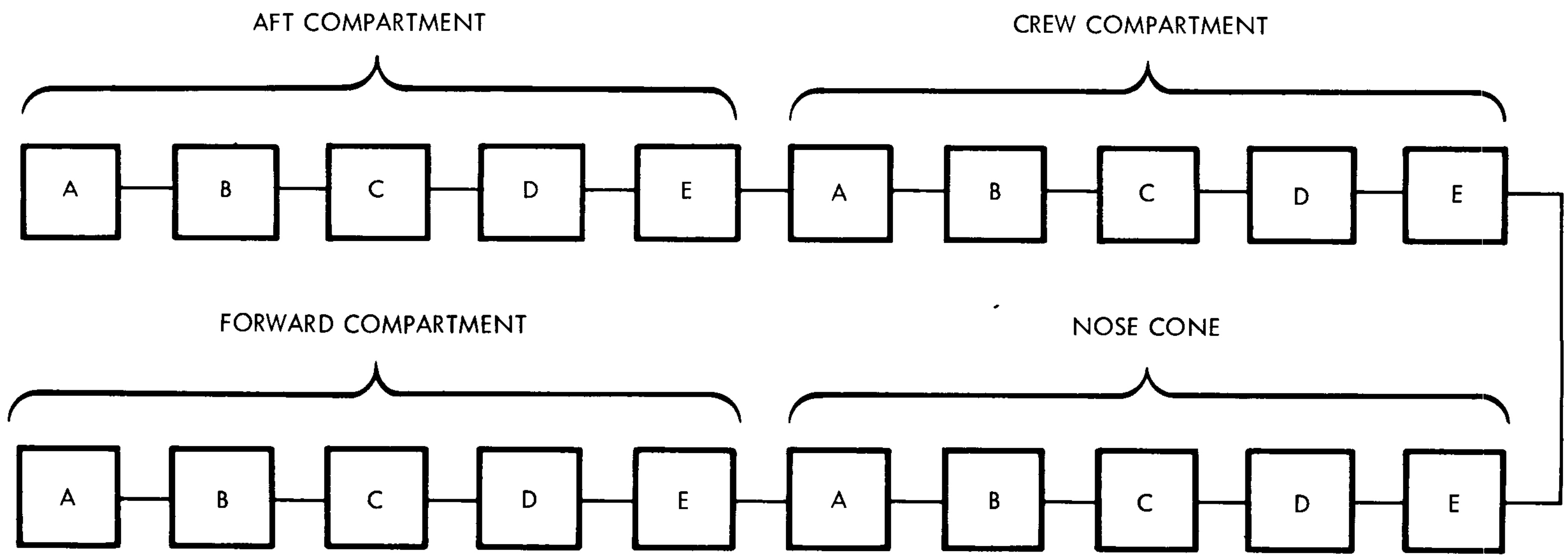
2.5.2 ANALYSIS

The results of a reliability assessment of the Apollo heat shield at heating location 304, located at the aft end of the command module crew compartment, is provided in Avco Monthly Progress Report RAD-SR-65-53. The assessed reliability to meet the backface temperature criteria was found to be 0.4338, with 90-percent confidence. Variations inherent in the physics of the vehicle and the reentry path were not considered in the assessment. Vehicle protection at backface temperatures less than 600 F was assumed; hence, the assessment predicts how often this temperature will be exceeded. The backface temperature is a complex function of heat shield geometry, reentry pattern, and physical properties of the heat shield. These quantities all vary with location and time. Much of the validity of the assessment technique used is based on the assumption that all variables which affect the backface temperature are physical in nature, i.e., that the mathematical design model is perfectly rigorous and that the mission environment is perfectly defined. In reality, neither of these conditions is true. It is possible for example, that inherent conservatism or bias in the model may always tend to over predict temperature. This has been the experience gained through numerous ballistic missile flight tests analyses where similar design techniques were used. Additional details of this assessment can be found in the referenced report.

A logic diagram and single-point failure summary for the heat shield were completed and are shown in Figure 2-5 and Table 2-3, respectively.

2.5.3 TEST PROGRAM

Avco is developing techniques for improving the sensitivity and amplifying contrast in radiography for detection of ablator defects. Five different types of photosensitive materials that produce both transparencies and prints have shown promise as copying media. Studies to determine their capability in this application are in progress.



LEGEND

A - ABLATIVE MATERIAL
B - PHENOLIC HONEYCOMB
C - ABLATOR TO SUBSTRUCTURE BOND
D - NONHOMOGENEOUS AREAS
E - NONHOMOGENEOUS AREAS BOND

Figure 2-5. Heatshield Logic Diagram

Table 2-3. Ablative Heat Shield Subsystem Single-Point Failure Summary

Part Number and Nomenclature	Failure Modes or Experience-Related Problems	Probable Cause During Mission (Environmental or Functional)	Probability of Occurrence During Mission	Failure Effect Upon: Crew	Failure Effect Upon: Primary Mission Objectives	Corrective Action Required	Ground Tests Indicating Damage
Main ablator	Local overheating during reentry	Discontinuous separations between: 1. Honeycomb and ablator pencils 2. Honeycomb ribbons at node locations 3. Ablative material within cell					
		Ablator spalling Plastic yielding					
	Local or widespread overheating depending upon degree of failure	Continuous bond separation along cell perimeter	Unknown	Yes	Yes	None at this date	No flight or ground qualification tests have been conducted to date
		Continuous separation encompassing several cells					
		Honeycomb to substructure bond fails					
	Local overheating during reentry	Excessive ablation of ablator surrounding perturbations					
Shear-compression pads	Loss of shear load resistance between S/M and C/M	Crushing of pad due to excessive loading					
	Local overheating	Bond failure fracture					
	Loss of compressive load capability						
Fiberglass edge member	Local or widespread overheating	Separation of Honeycomb from outstanding leg					

Table 2-3. Ablative Heat Shield Subsystem Single-Point Failure Summary (Cont)

Part Number and Nomenclature	Failure Modes or Experience-Related Problems	Probable Cause During Mission (Environmental or Functional)	Probability of Occurrence During Mission	Failure Effect Upon		Corrective Action Required	Ground Tests Indicating Damage
				Crew	Primary Mission Objectives		
Ablator plug and housing	Local overheating	Fracture or separation of housing or plug					
C-band antenna interface	Severe overheating of substructure	Separation and spalling of fiberglass	Unknown	Yes	Yes	None at this date.	No flight or ground qualification tests have been conducted to date.
Oxidizer dump interface	Local overheating	Excessive ablation of Honeycomb ablator at interface due to perturbations					
Engine ablator panels	Local overheating	Same as main ablator					
Joint filler (gasket)	Local overheating	Permanent deformation, cold flow or fracture of gasket material					
Bolt assembly plug	Local overheating	Fracture and separation of ablator plug or housing					
Window, fixed edge member	Local or severe overheating	Air flow perturbations Molded ablator cracks or separates					
Umbilical connector interface	Local or severe overheating	Degradation of ablator by chemical reaction Fracture of ablator adjacent to connector					

Table 2-3. Ablative Heat Shield Subsystem Single-Point Failure Summary (Cont)

Part Number and Nomenclature	Failure Modes or Experience-Related Problems	Probable Cause During Mission (Environmental or Functional)	Probability of Occurrence During Mission	Failure Effect Upon		Corrective Action Required	Ground Tests Indicating Damage
				Crew	Primary Mission Objectives		
Vent interface Scimitar antenna interface	Local or severe overheating	Same as C-band antenna interface	Unknown	Yes	Yes	None at this date.	No flight or ground qualification tests have been conducted to date
Abort tower well	Local overheating	Fracture or loss of bond					
Engine access panel	Same as main ablator	Same as main ablator					

2.5.4 PROBLEM AREAS

An investigation of the cracks in the inner face sheets of the crew compartment heat shield on Spacecraft 009 started in May 1965. A general pattern of cracking, parallel and tangent to the radius of the chem-milled inner face sheet, was established. Preliminary analysis, using curves based on photo-elastic data, indicate stress concentration factors (K_t) may be as high as 1.4 in this area. These abrupt stress transitions are aggravated by residual stresses resulting from transverse weld shrinkage during face-sheet welding and intermittent welds on the pad. Additional stress in the face-sheet resulting from strain induced by such operations as handling and packing also contribute to the failure. (Later investigation by Materials Review revealed these cracks are more numerous than first anticipated.)

Reliability and the Materials and Producibility group recommended a change to the two-step chem-mill face sheet configuration which proved successful on another program.

2.5.5 PLANNED ACTIVITIES

Continued monitoring of heat shield development is planned.

2.6 LAUNCH ESCAPE

2.6.1 SUMMARY

Qualification of the launch escape subsystem (LES) motors was accomplished with the last successful static firing of the tower jettison motor on 25 May 1965. Thiokol had previously completed the failure investigation program resulting from the ignition delay of the 14th qualification tower jettison motor which was intentionally initiated with a single cartridge. Design changes to eliminate any potential ignition delay problem are being incorporated on motors for Spacecraft 012 and subsequent spacecraft. (Production motors utilize dual cartridges for ignition.)

Successful performance of the LES motors was noted on Boilerplate 22, although the mission objectives were not accomplished because of malfunction of the Little Joe II booster.

The proposed follow-on procurement specification for the launch escape and pitch control motor is being revised to incorporate NASA comments. The FMEA, logic diagrams, single-point failure summaries, minimum airworthiness requirements status, and predictions for LES motors required through Spacecraft 012 were completed.

A reliability audit was conducted at Lockheed for the launch escape and pitch control motors. Deficiencies in the handling of design review, failure mode effects and logic analysis, and instrumentation requirements were reported.

2.6.2 ANALYSIS

Mission requirements for Spacecraft 002, 009, 010, 011, and 012 were reviewed and logic diagrams prepared for the LES. Subsequently, reliability predictions for Spacecraft 011 and 012 were made based upon this logic. Failure mode and effects analysis, single-point failure summaries, and minimum airworthiness status were prepared for spacecraft through Spacecraft 012. No problems are known to exist within the LES motors fabricated to current requirements for these spacecraft.

Mission requirements are being analyzed to determine whether current requirements for the motor are stringent enough for possible mission conditions. Thrust levels are being evaluated for adequacy, trajectory analysis is being performed relative to possible points of booster failure and subsequent abort, and possible tower jettison motor redesign is being studied to prevent the spacecraft from passing through the plume of the tower jettison motor.

Thiokol presented the results of the failure investigation of the ignition delay of the 14th qualification tower jettison motor to NAA on 29 April 1965. The results of the failure investigation program are given in Thiokol Report A-026, which states that the most probable cause of ignition delay was expulsion of the cartridge charge or debris due to lack of any retention device on the initiator and booster.

The physical properties test sample for the launch escape and pitch control motor for Boilerplate 26 failed to meet the propellant-to-liner bond strength test, failing in the propellant area of the specimen. Analysis was performed showing that the tensile strength properties exhibited were sufficient. A statistical study was performed by NAA on ignition delay data submitted by Thiokol in Report A-025. The results of the study indicate that the probability of ignition delay is increased by the following conditions:

1. Use of a single igniter cartridge for ignition

2. Use of high crush-strength pellets

3. Use of aged pellets.

Requirements for a program to verify adequacy of pellets stored within motors for long periods of time are being studied.

A design review of the LES was held, and problems directed to Reliability included the pellet-aging problem mentioned previously.

2.6.3 TEST PROGRAM

Qualification testing of the LES motors was completed with the firing of the last tower jettison motor on 25 May 1965. Changes which resulted from the failure investigation test (FIT) program of the ignition delay of the 14th qualification tower jettison motor remain to be incorporated on production motors for Spacecraft 012 and subsequent spacecraft. These changes include:

1. Addition of a seal over the pyrogen nozzle to prevent vacuum exposure of the ignition system

2. Design of a retention for the initiator end cap to prevent a "pistoning" effect on the booster charge.

3. Design of a retention for the booster portion of the igniter cartridge to prevent expulsion of the charge or debris.

4. Deletion of one layer of mylar tape from the pellet basket.

The effect of aging of boron pellets on ignition delay was studied, and a proposed surveillance test is under consideration to verify the integrity of stored or otherwise aged pellets prior to use in a launch vehicle.

The specifications for the follow-on production launch escape and pitch control motors reported in the 13th quarterly progress report were rewritten to comply with NASA requests. The specifications will include provision for limited qualification verification testing. It is planned that an incentive provision be included in the specification to encourage the supplier to control variation of burning rates for propellant batches and to maintain a margin above the lower specification thrust limit that is statistically consistent with the burn-rate variation obtained.

Failure reports for the LES motors were reviewed and all open reports were closed out from the master failure tape, which is updated and submitted monthly to NASA.

The flight of Boilerplate 22 demonstrated the ability of the LES to function satisfactorily in the event of an emergency. The mission was aborted automatically due to a failure and subsequent explosion of the booster. The flight objectives included an evaluation of the canards in a thin atmosphere, but this was not accomplished due to abort initiation of the LES motors.

2.6.4 SUBCONTRACTOR MANAGEMENT

A reliability audit conducted at Lockheed Propulsion Company on 25 and 26 March 1965 revealed deficiencies in the updating of documentation to reflect advancing program technology. The audit report requested submittal of an updated reliability program plan consistent with current program stage and itemizing-developed techniques of reliability program control, including statistical methods to assess process control, criteria for acceptance or rejection of production motors and propellant batches, and reliability analysis techniques of prediction based on propellant burn rates. It was requested that the plan also make reference to a continuing reliability assessment for the follow-on program and describe any reliability control techniques used. In addition, the audit report requested updated versions of the logic and failure mode and effects analyses, final disposition of all design review recommendations, and immediate verbal notification of all acceptance or process failures to Apollo Reliability.

2.6.5 PLANNED ACTIVITIES

The qualification report for the tower jettison motor will be submitted and evaluated during the next report period, and will contain the final supplier reliability assessment of the tower jettison motor.

Contracts for follow-on production runs for the LES motors should be negotiated with the suppliers during the next report period.

Block II reliability logic incorporating failure mode analysis will be completed for the LES motors during the next report period.

2.7 MECHANICAL DEVICES

2.7.1 SUMMARY

The manually-operated cabin pressure control successfully completed qualification testing. Reliability analyses for the uprighting system, the astro-sextant doors, and the manually-operated cabin pressure control were completed.

2.7.2 ANALYSIS

The single-point failure summaries for the astro-sextant doors and manually-operated cabin pressure control were completed and are shown in Tables 2-4 and 2-5, respectively.

A logic diagram (Figure 2-6) and a revised single-point failure summary (Table 2-6) were generated for the uprighting subsystem.

2.7.3 TEST PROGRAM

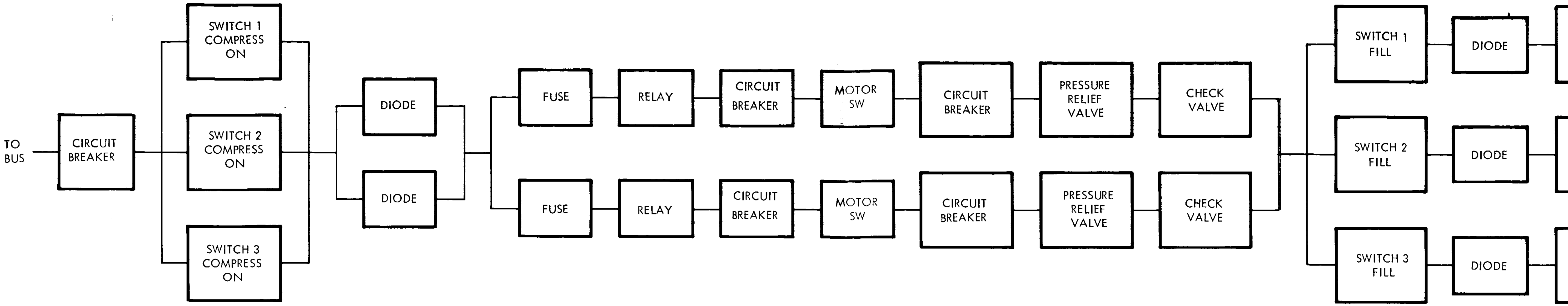
Further delay of qualification tests on the astro-sextant door actuator was caused by the necessity for rework of the actuators with dimensional errors.

Qualification tests of the manually-controlled cabin pressure control were successfully completed, but the final report, scheduled for release in May, has not been received.

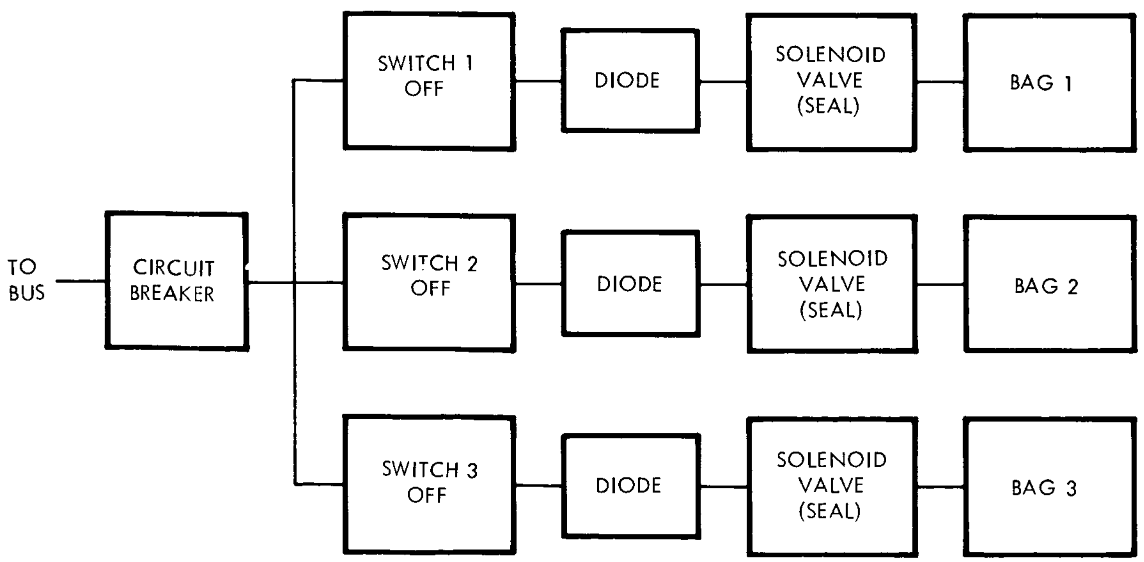
The faulty needle-bearing problem in the screwjack was solved by re-honing the bearings. One unit successfully completed acceptance testing.

2.7.4 PLANNED ACTIVITIES

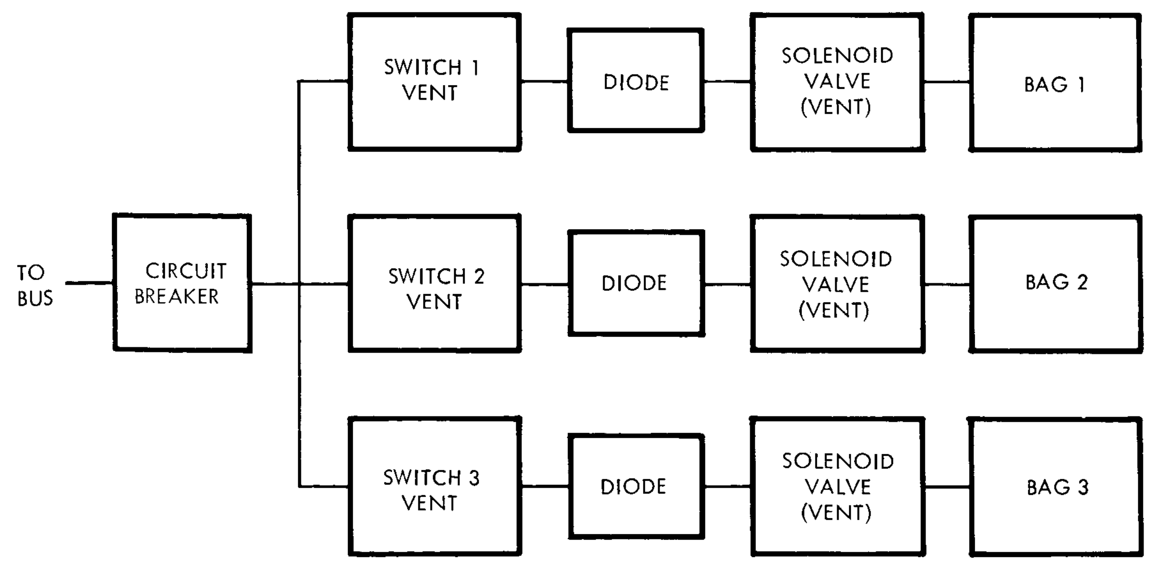
Additional logic diagrams, single-point failure summaries, and failure mode and effects analyses will be generated during the next report period.



FILL CYCLE LOGIC



SEAL CYCLE LOGIC

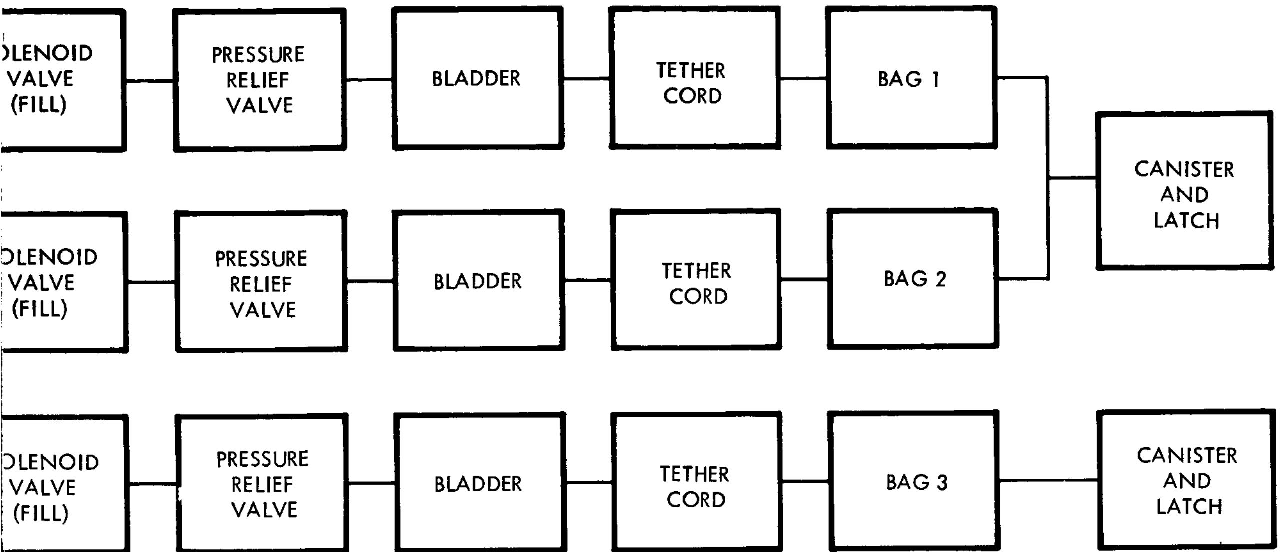


VENT CYCLE LOGIC

NOTES:

1. BAGS ARE
2. TWO OF T
3. DELETE SW

FOLD-OUT #1



ILLED, SEALED, AND VENTED ONE AT A TIME
IE THREE BAGS MUST FILL FOR SUCCESSFUL SUBSYSTEM OPERATION
TCHES FOR UNMANNED VEHICLES, REPLACE WITH SEQUENCER

FOLD-OUT #2

Figure 2-6. Uprighting Subsystem Logic Diagram
(Spacecraft 011, 012, 014, 017, and 020)

Table 2-4. Actuating and Latching, Astro-Sextant Doors Single-Point Failure Summary—Spacecraft 012 and Subsequent Vehicles

Part Number and Nomenclature	Failure Modes or Experience-Related Problems	Probable Cause During Mission (Environmental or Functional)	Probability of Occurrence During Mission	Failure Effect Upon		Corrective Action Required	Ground Tests Indicating Damage
				Crew	Primary Mission Objectives		
Drive assembly V16-550600	Binding, breakage	Structural					
Hermetic drive ME 147-0004-0001	Binding, breakage	Structural					
Differential gear box ME 147-0005-0001	Binding, breakage	Structural vacuum-temperature					
Rotary flex shafts (4) ME 145-0001	Binding, breakage	Structural vacuum-temperature	Unknown	Doors fail open; crew is lost	Doors fail open or closed; primary mission objectives are not achieved	Provide alternate mode for closing doors	None
Screwjack ME 148-0010-0001	Binding, breakage Allows latches to close before doors close	Structural vacuum-temperature					
Hinge drive V16-550555	Binding, breakage	Structural vacuum-temperature					
Latches and linkage	Binding, breakage	Structural vacuum-temperature					
Doors	Doors warp and cannot be closed	Temperature				Tests should be conducted on unmanned flight vehicle to determine if problem exists	

Table 2-5. Cabin Pressure Control Single-Point Failure Summary—Spacecraft 012 and Subsequent Vehicles

Part Number and Nomenclature	Failure Modes or Experience-Related Problems	Probable Cause During Mission (Environmental or Functional)	Probability of Occurrence During Mission	Failure Effect Upon		Corrective Action Required	Ground Tests Indicating Damage
				Crew	Primary Mission Objectives		
Cabin pressure control, manually-actuated ME 901-0255	Accidently or inadvertently placing of lever in dump position when crew is out of suits	Mental faculties impaired due to zero-g or human error	Low	Loss of crew or crewman	Loss of primary mission objectives	The four-position lever assembly should contain a special feature so that a crewman cannot position the lever to dump as easily as the other three positions	Qualification tests completed successfully

Table 2-6. Uprighting Subsystem Single-Point Failure Summary—Spacecraft 011 and 012

Part Number and Nomenclature	Failure Modes or Experience-Related Problems	Probable Cause During Mission (Environmental or Functional)	Probability of Occurrence During Mission	Failure Effect Upon: Crew	Failure Effect Upon: Primary Mission Objectives	Corrective Action Required	Ground Tests Indicating Damage
Double bag canister assembly V16-586519-11--assembly consists of 1 canister, 2 bladders, and 1 latch (contains 2 bags)	Latch fails to open	Linkage binds	Unknown	Does not apply	Yes	None - space limitations require use of single canister for two bags; design revised for Block II	No tests to date
	Latch opens prematurely	Vibration shock	Unknown				
Circuit breaker C15AGCB68	Jams open	Shock	Low			Redesign of circuit	
Single-ground return for compressor relays	Breaks	Shock	Low			Provide separate ground returns	
Single power source lead for compressors	Breaks	Shock	Low			Provide dual leads	

2.8 ORDNANCE

2.8.1 SUMMARY

Qualification tests of the standard hotwire initiator, completed by one of the two suppliers, resulted in four failures in the low-temperature firing tests, and a delta qualification test program is in progress to rerun the two test groups in which the failures occurred. Development tests were completed for the Block I command module-to-service module umbilical guillotine. The main chute disconnect for Block I vehicles was redesigned with blade cutters to replace linear-shaped charges. The design of a new disconnect for main and drogue chutes on Block II vehicles was completed.

The launch of Boilerplate 26 was completed successfully with single-mode explosive bolts in the tower separation system. An abort made from the Boilerplate 22 launch vehicle included successful operation of the single-mode explosive bolts, forward heat shield separation system, canard system, CM-SM separation, pilot and drogue chute mortars, dual-drogue disconnect, and escape motor ignition. Two reefing line cutters, however, failed to fire.

2.8.2 ANALYSIS

Preliminary failure mode effect analyses were completed for all Block I ordnance systems, and single-point failure summaries were completed for Spacecraft 009, 011, and 012. Logic diagrams for the electrical circuit interrupter, SLA panel thruster, SLA panel shock attenuator, SLA spring reel, main chute disconnect (Block I), HF recovery antenna deployment, and main and drogue chute disconnect (Block II) are shown in Figures 2-7 through 2-13.

2.8.3 PROBLEM AREAS

2.8.3.1 Hotwire Initiator

Four failures occurred in low-temperature firing tests (-260F) during the qualification test program for the hotwire initiator: two were failures to fire and two were excessive times to peak pressure. A failure analysis by the supplier concluded that the failures were caused by faulty manufacturing procedures. A new lot of initiators was fabricated and a delta qualification test program was in progress at the conclusion of the report period to rerun the two test groups (62 units) in which the failures occurred.

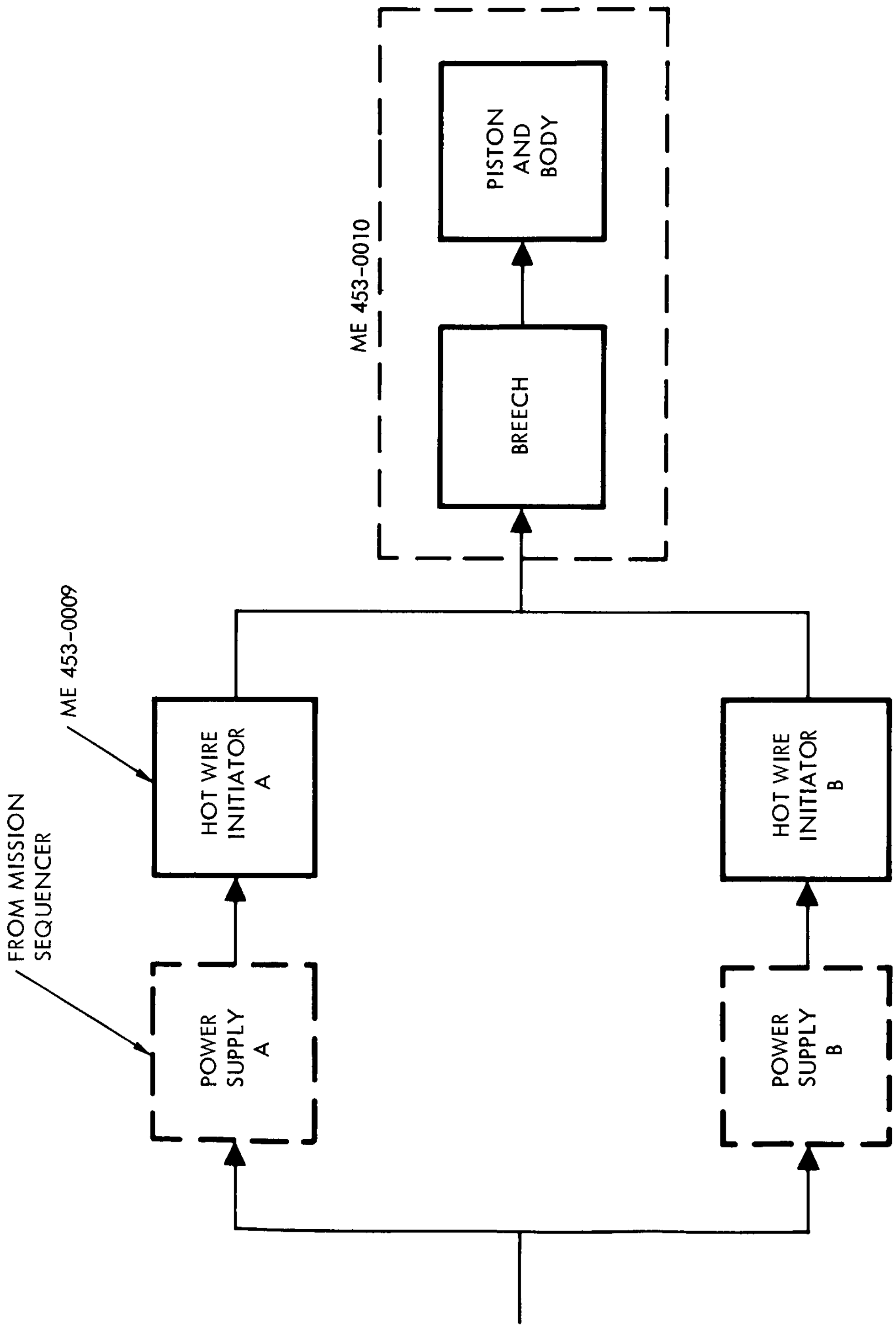


Figure 2-7. Electrical Circuit Interrupter Logic Diagram

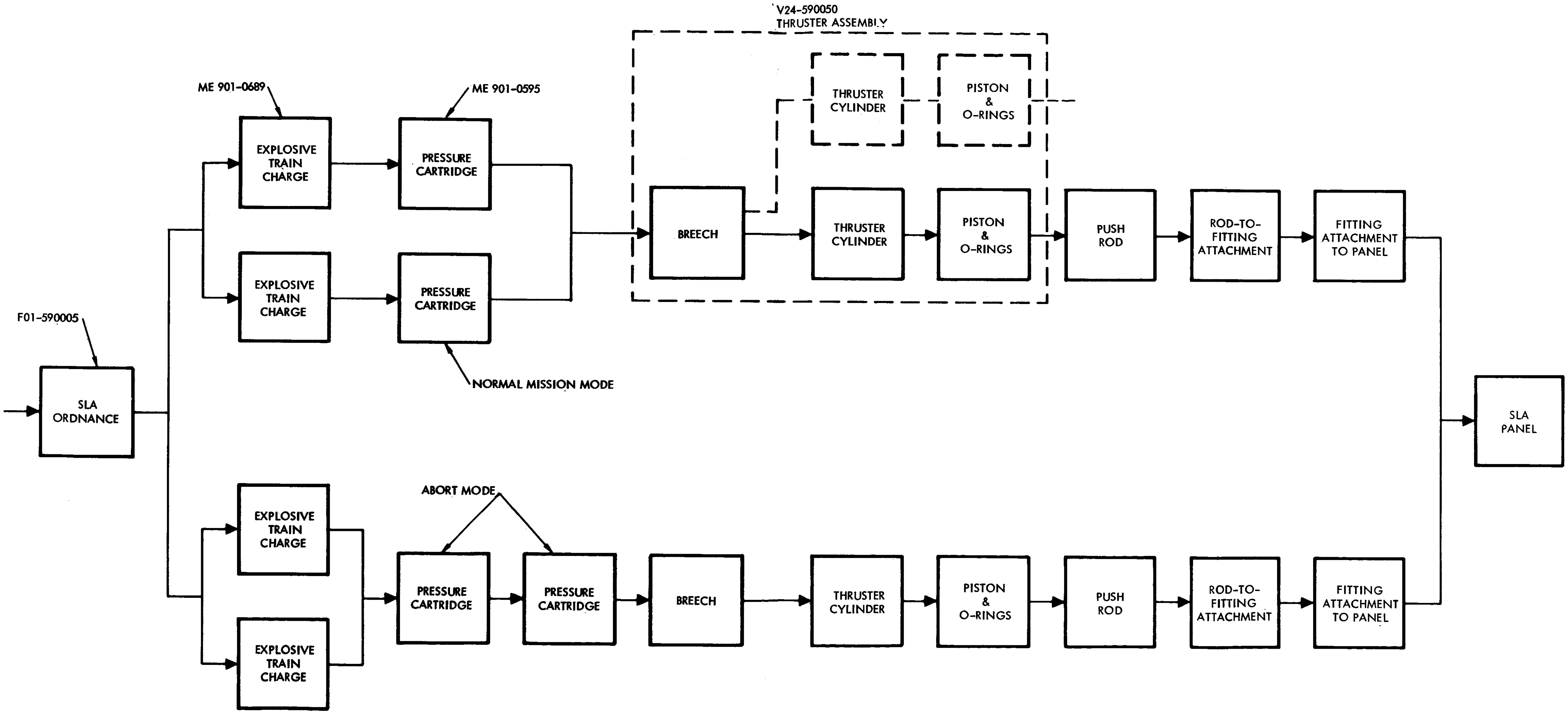


Figure 2-8. SLA Panel Thruster Logic Diagram
(Typical for Each of Four Panels)

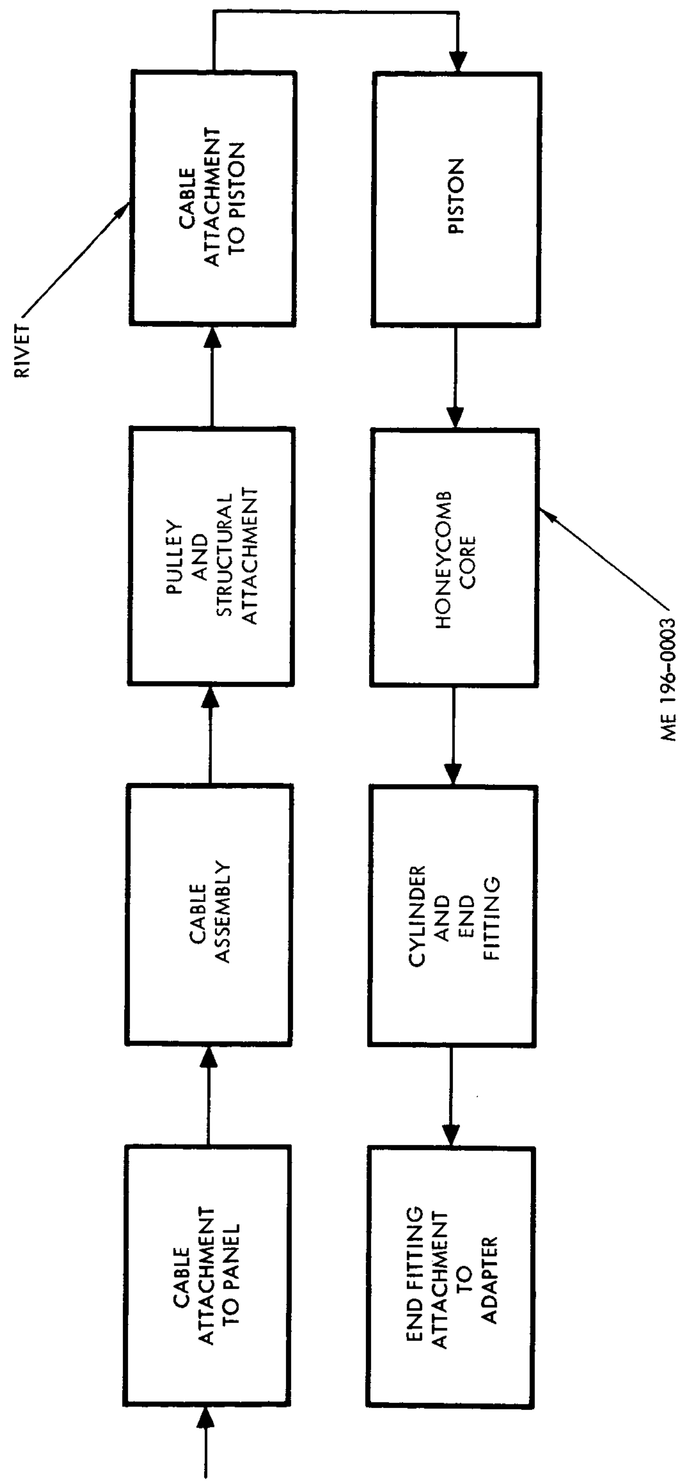


Figure 2-9. SLA Panel Shock Attenuator Logic Diagram

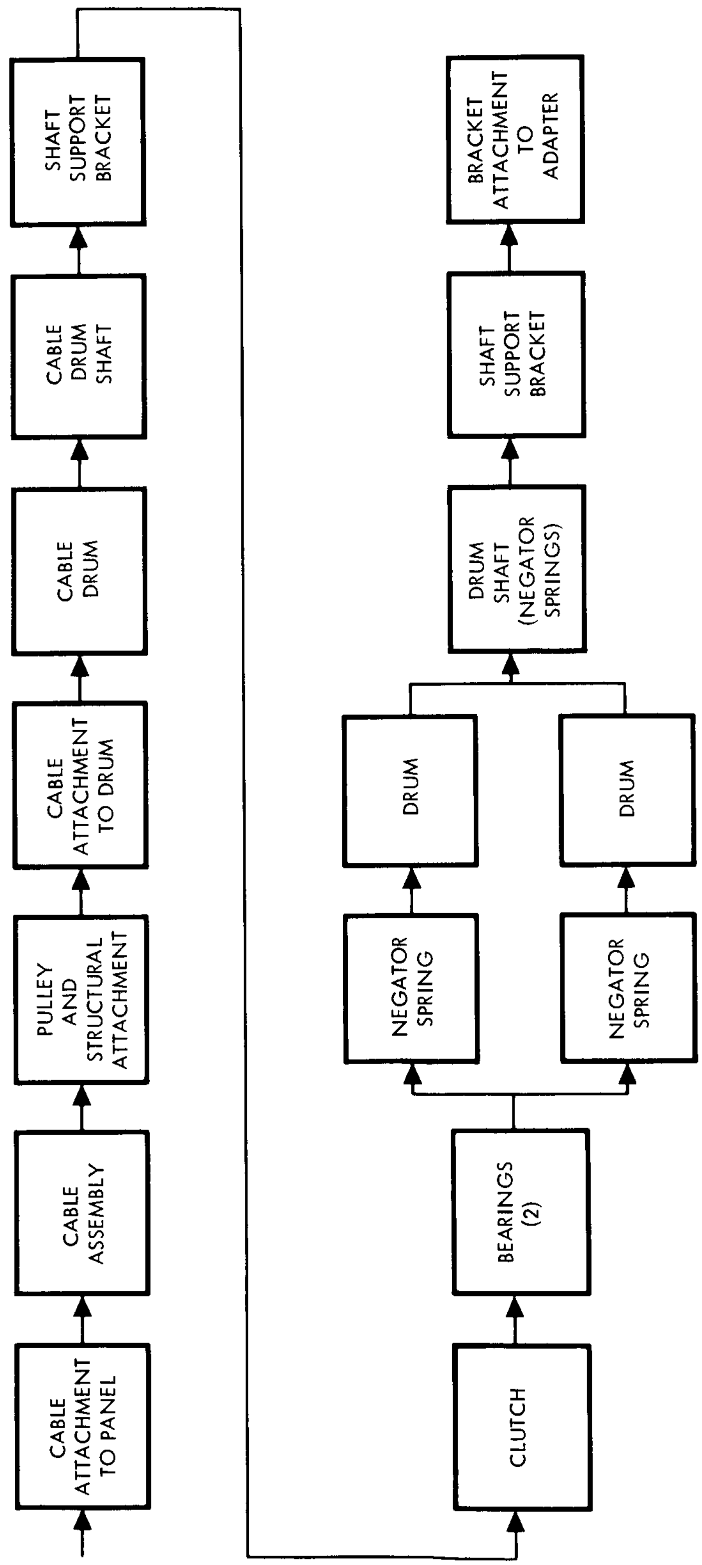


Figure 2-10. Spring Reel Cable Assembly Logic Diagram (SLA Panel Deployment)

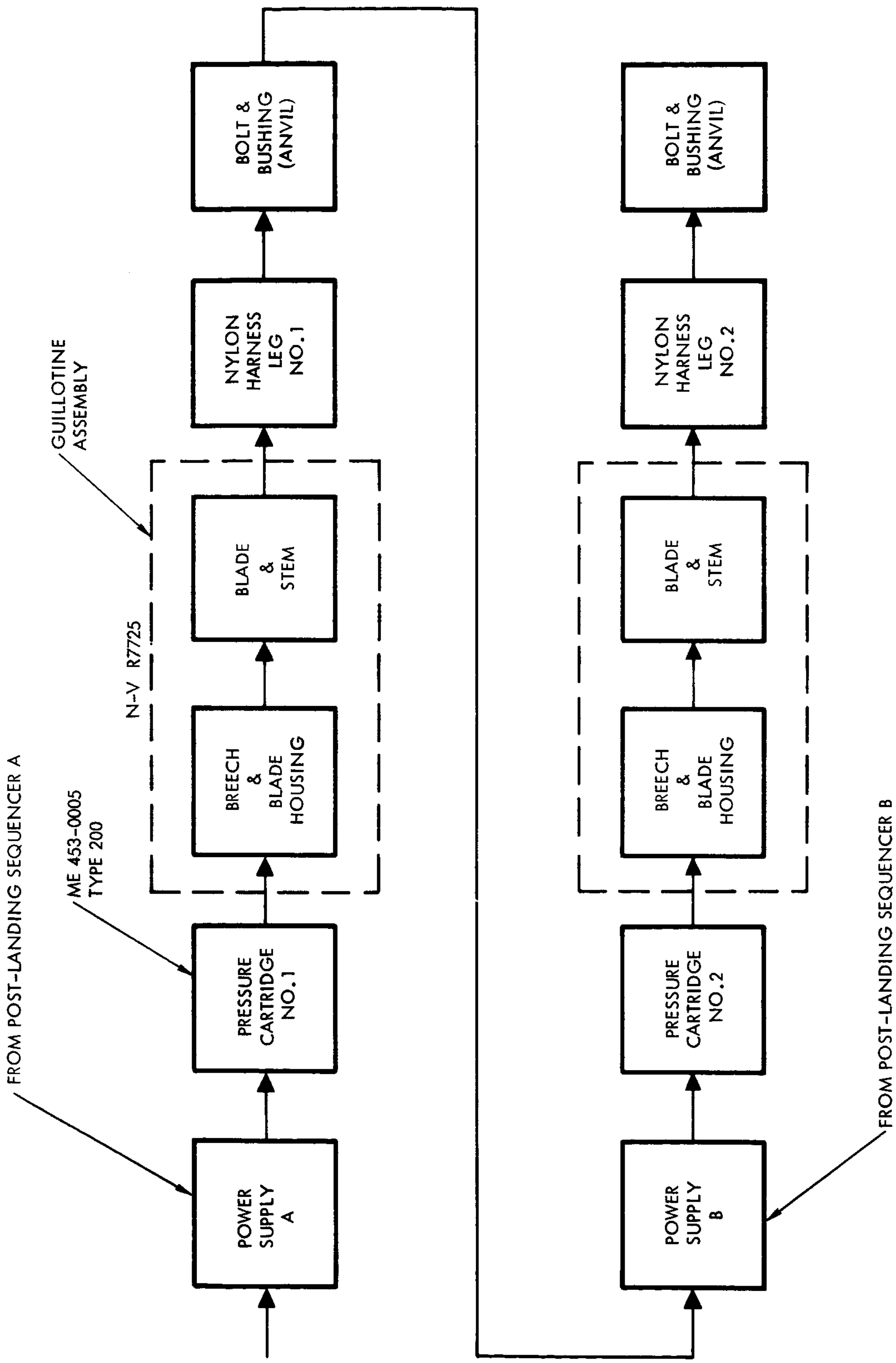
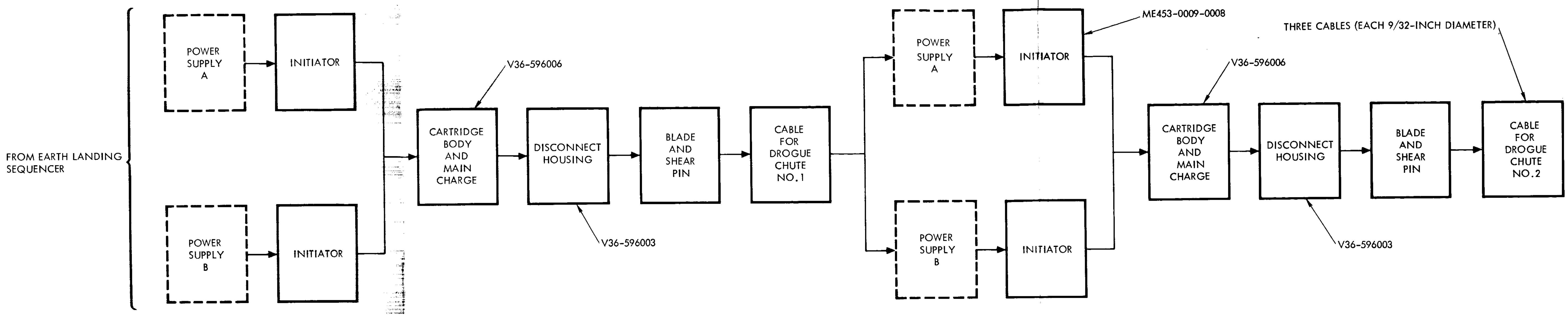
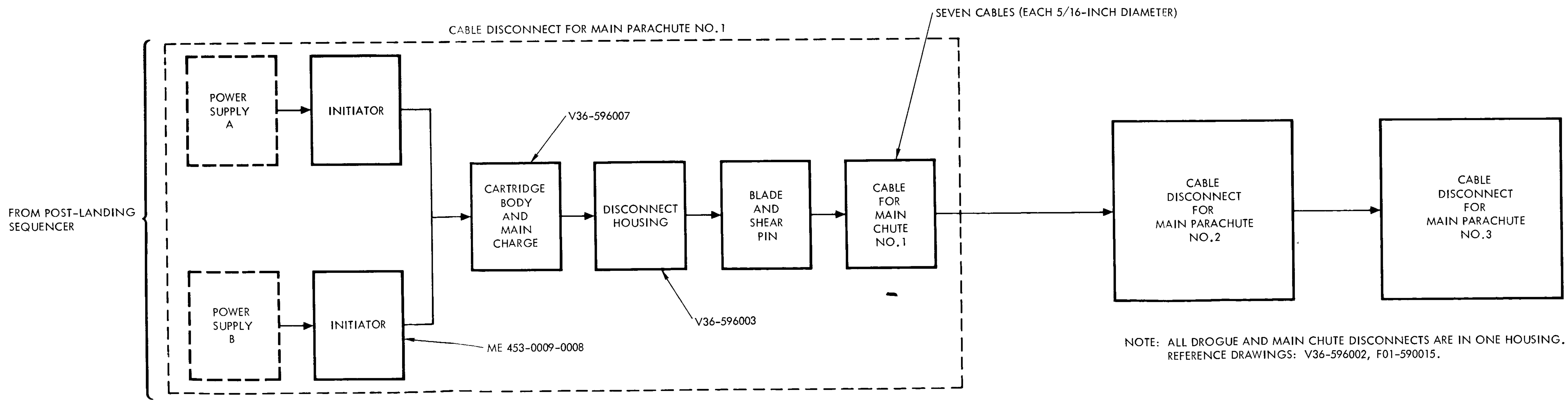


Figure 2-11. Main Chute Disconnect, Block I, Logic Diagram



LOGIC DIAGRAM FOR DUAL DROGUE CHUTE DISCONNECT - BLOCK II



LOGIC DIAGRAM FOR THREE MAIN CHUTE DISCONNECTS-BLOCK II

Figure 2-13. Main Chute and Drogue Chute Disconnects Logic Diagram, Block II

2.8.3.2 Dual-Mode Bolt

Two failures occurred in the prototype qualification test program for the dual-mode bolt. In each case, the bolt failed to separate at the notch when fired in the cutter mode, although the blade separated successfully. Corrective action was to heat treat the cartridge body to achieve greater strength in the thread and prevent the cartridge plug from blowing out. The requirement for separation at the notch in the cutter mode was also under review.

2.8.3.3 Type VI Pressure Cartridge

A failure occurred in the prototype qualification test program of the Type VI pressure cartridge for the forward heat shield separation system due to the rupture of a cartridge body when the unit was fired at low temperature (0 F). Corrective action for the cartridges used on Boilerplate 22 was to increase the wall thickness. Future Type VI cartridges will be procured from a new supplier and will incorporate the increased wall thickness.

2.8.3.4 Reefing Line Cutters

Two reefing line cutters failed to fire in the aborted flight of Boilerplate 22. Corrective action is expected to include redesign, but the line cutters for the VHF antenna and flashing-light deployment systems will be procured from another supplier. Two failures occurred during vibration tests of the explosive train charges for the SLA separation and panel deployment system. Corrective action will be to improve support of the mild detonating cord inside the protective tubing and to redesign the cord-to-booster interface.

2.8.4 PLANNED ACTIVITIES

During the next report period the following tests will be in progress:

1. Component qualification tests that include hotwire initiator, igniter cartridge, detonator cartridge, explosive train charge, confined detonating cord, explosively initiated pressure cartridge, electrical circuit interrupter, flexible linear shaped charge, pressure cartridges for drogue and pilot chute mortars, canard thruster, forward heat shield thruster, and propellant valve.

2. System qualification tests that include canard thruster, forward heat shield separation, dual-drogue disconnect, CM-to-SM tension tie to cutter, CM-to-SM umbilical guillotine, and SLA separation and panel deployment.

3. System development tests that include Block II CM-to-SM separation system and umbilical disconnect, LEM docking mechanism separation, and Block II main and drogue chute disconnect.

These tests and any resulting failures will be under surveillance during the next report period.

2.9 REACTION CONTROL, COMMAND MODULE

2.9.1 SUMMARY

A supplemental test program on the squib-operated valves was implemented to rectify the proposed data reduction and assessment techniques. Results of this test program will be reported in the 15th Quarterly.

A back-up program for the propellant isolation valve is progressing satisfactorily, and the new design is scheduled for Spacecraft 011 and subsequent vehicles.

The command module reaction control subsystem (RCS) regulators completed qualification testing, with the rocket engine experiencing six failures.

Problems experienced during development of the check valves, and helium isolation valves are being investigated.

The failures of the burst disc during qualification have not been resolved, and the decision to restart qualification is pending.

2.9.2 ANALYSIS

2.9.2.1 RCS Rocket Engine

NAA/S&ID approval of the subcontractor steady-state error analysis is still pending, as reported in the 13th Quarterly Report, SID 62-557-13. The information submitted during this report period requires additional clarification. The acceptance test procedure was revised to delete the pulse series test; however, this test is still a qualification test requirement. The error analysis test program was completed in June 1965, and the test results and analysis will be presented in the next report period.

2.9.3 PROBLEM AREAS

2.9.3.1 CM and SM RCS and SPS Check Valves

The re-evaluation of propellant compatibility, temperature, and propellant exposure duration requirements for the CM RCS, SM RCS, and service propulsion subsystem (SPS) check valves, as reported in

SID 62-557-12, resulted in a substantial increase in requirements. Tests conducted by the valve supplier to determine the feasibility of using Teflon as a valve poppet seal material were reported successful. The supplier now reports, however, that they are unable to produce units of this design that can pass the S&ID acceptance tests for internal leakage because of the permeability of the Teflon seat material and permanent deformation of the Teflon due to exposure to nitrous oxide.

Efforts to develop a new valve seat material (nitroso compound) for the CM and SM RCS valve is proceeding and results are encouraging. The course of action to resolve the development problems of the SPS check valve has not yet been determined.

2.9.3.2 CM and SM RCS Helium Isolation Valves

The CM and SM RCS helium isolation valves (MC284-0001) experienced repeated leakage and latch failures. Corrective action implemented to correct these failures included re-evaluation of the seat design (seat material and means of fabrication) and performance of a vibration test penalty run to further define the tendency for valve latch failure. The supplier evaluated the present valve design relative to the new propellant exposure design requirement and submitted the same basic design configuration for the new design requirement.

In view of the above, S&ID is evaluating proposals for a back-up program for the valves.

2.9.3.3 CM RCS Isolation Valve Burst Diaphragm

Revision B of the procurement specification will necessitate changes to the isolation valve because of the new test requirements. The current qualification testing will be discontinued and the qualification test program revised to reflect the Revision B requirements.

The factors contributing to the failures reported during qualification testing were not definitely resolved. Electropolishing of the burst disc groove is being investigated. The supplier obtained several metallic seals, V seals, K seals, and microseals for evaluation and is testing Alodine-, Iridite-, and Teflon-coated burst disc assemblies. In addition, a study is being conducted to minimize secondary stresses induced during assembly.

2.9.3.4 RCS Rocket Engine Assembly (REA)

Six test failures occurred during the qualification testing of the REA:

1. The nozzle extension seal leakage was 562 scc of helium per hour, although the maximum allowable is 20 scc. The qualification test procedure was revised to allow leakage of less than 600 scc of helium per hour to allow continuation of qualification testing.

2. During pulse operation, the REA failed to meet the pulse performance requirements. Pulse performance at 20 milliseconds was 6 percent low. During pulse performance at 100, 150, and 200 milliseconds (ms), the pulse width was low by one percent. The supplier reported the propellant feed system (facility test-stand) characteristics or instrumentation error could explain the apparent loss in specific impulse, with the loss of thrust coefficient efficiency being the contributing factor. Modifications to the facility were completed on 18 May 1965. The instrumentation error analysis discussing the pulse instrumentation requirements and the degree of confidence in meeting these requirements will be completed in June 1965.

3. During installation of the nozzle extension, the NAS-1122-C9 bolts could not be installed using the maximum torque allowable of 18 inch-pounds. The cause of the failure was attributed to epoxy in the nozzle inserts, and the supplier initiated the following production improvements:

    a. Tooling used to install insert assemblies was modified.

    b. An amendment was made to the applicable process specification that ensures control of the amount of bonding material in the inserts and minimizes the flow of bonding material under load.

    c. The inspection check fixture was modified.

    d. The inspection technique was changed to require an unobstructed clearance hole and to allow insertion of the screws in the insert-locking feature with only free-running torque.

4. The mixture ratio under standard conditions did not meet the qualification specification requirements of 2.0±0.065. The qualification verification test recorded a mixture ratio of 2.103, based on the average of two tests; the acceptance test mixture ratio was

reported at 2.040, also based on the average of two tests. The following retests and testing was performed by the supplier prior to throat insert failure.

a. Performed Freon flow check on the engine

b. Subjected the engine to humidity and salt fog tests

c. Removed and replaced the orifices and orifice holders and rechecked Freon flow

d. Conducted hot-fire calibration verification (programmed for 3 seconds). The throat insert failure occurred approximately one second after engine start. Apparently, as indicated by the preliminary test results (one second of operation), the problem of mixture ratio was corrected.

5. During calibration a 360-degree circumferential crack developed. Approximately one-third of the insert was ejected, causing a shift in performance which was out of specification.

   The supplier reported that a low-density, high porosity throat insert will crack if hot-fired immediately after long exposure to moisture. The supplier revised their process specification to require performance of density checks on billet stock (sufficient for two throat assemblies) and finished throat insert assemblies.

   Based on the preliminary results of the failure investigation, which attributed the failure to an insufficient drying period of throat insert prior to hot-firing, the supplier was directed to restart qualification testing. The failed REA was subjected to humidity and salt fog environmental tests, extensive Freon flow tests (approximately three times that normally required) after re-orificing, and approximately one hour of vacuum drying at 1 psi prior to hot-firing.

2.9.3.5 CSM RCS Propellant Tanks

The service module fuel tank configuration, as reported in the 13th Quarterly, SID 62-557-13, passed the qualification test requirements. The two specimens of the oxidizer tank configuration failed: one failure occurred when the liquid side vent tube broke and the second occurred as a result of a small tear in the bladder. The liquid side vent tube failure was traced to the welding procedures and corrective action was implemented; the service module oxidizer tank bladder failure is still under investigation. A bladder failure on the command module oxidizer tank, which occurred after three cycles during design and verification testing, is also being investigated.

2.9.3.6 CSM RCS Propellant Isolation Valves

The inability of the current supplier of the MC 284-0013 and -0045 valves to produce hardware capable of reliably performing its intended task resulted in a backup program. Procurement of a replacement valve, MC 284-0276 was implemented. Effort is scheduled to continue on the MC 284-0013 and -0045 valve configurations through design verification test, but qualification and off-limit testing on these units was cancelled. The MC 284-0276 propellant isolation valve is scheduled for Spacecraft 011 and subsequent vehicles, and development on this unit is proceeding on schedule.

2.9.4 TEST PROGRAM

2.9.4.1 RCS Squib-Operated Valves

The qualification program revision as outlined in SID 62-120 is being implemented. The supplier submitted, and S&ID approved, the supplemental test plans for the 1/4-inch and 5/8-inch valves. Series A of the supplemental test program, which was started at the supplier's facility on 26 May 1965 and is scheduled for completion 11 June 1965, verifies the proposed data reduction and assessment techniques. The series consists of firing five initiators into a fixed minimum volume and recording the generated peak pressure. The data will be reduced and the k factor relating the 10 cc bomb test to the minimum case will be calculated. This k factor was used to predetermine the correct shear area for a series of six shear fittings required to complete series A testing: two fittings are designed to deform but not shear, two are in the nominal shear area range, and the remaining two are minimum shear area capable of withstanding the 4500-psi inlet pressure.

The results of this test series are being reduced and critical parameters will be reported in the 15th Quarterly Report.

2.9.4.2 CSM RCS Helium Pressure Regulator Unit

Qualification testing on the command and service module RCS regulator is complete; however, the data has not yet been reduced and formal notification of completion is expected during the next report period.

The parallel flow and surge pressure test program was completed and test reports will be ready during the next report period. Production hardware was incorporated in this test program.

2.9.5 SUBCONTRACTOR MANAGEMENT

Reliability audits of APCO, National Waterlift, Sargent Fletcher, Pelmec, and Bell Aerosystems were completed during the report period. Directives which will correct the deficiencies of each supplier's reliability program are awaiting management approval.

2.9.6 PLANNED ACTIVITIES

End-item support will be sustained, including preparation of logic diagrams, single-point failure summaries, minimum airworthiness requirements, reliability preductions, and FMEA's for the individual spacecrafts. In addition, qualification test program monitoring will increase during the next report period.

2.10 REACTION CONTROL, SERVICE MODULE

2.10.1 SUMMARY

Effort was expended in all phases of subcontractor and supplier management, including reliability audits of the rocket engine subcontractor and the propellant quantity gaging supplier facilities, with the basic objective of determining conformance to the contractual requirements of the NAA/ S&ID reliability program requirements.

A failure of the rocket engine propellant valve stopped shipment of qualification configuration engines until corrective action had been taken.

The propellant quantity gaging system accuracy problems have not yet been resolved. The introduction of integrated circuits is expected to improve system operation.

2.10.2 ANALYSIS

The subcontractor submitted FMEA's and assessments on the rocket engine valves. Rocket engine apportionments and logic diagrams for the qualification configuration were received and are being reviewed. FMEA's and assessments on the qualification configuration engine are pending.

2.10.3 PROBLEM AREAS

2.10.3.1 SM RCS Propellant Quantity Gaging

System accuracy of the RCS propellant quantity gaging system continues unresolved, with additional problems in the areas of temperature sensitivity, failure of the automatic gain control subsystem to reset after a power interruption, and sensitivity to ripple on the d-c power input. Correction of the present sensor design appears impractical, but a different sensor design, using integrated circuits, is expected to result in improved stability, accuracy and reliability. Part specifications for the new components are being generated and implementation of the new design is expected by August 1965. The high rejection rate of "freeze-coated" modules immediately after the potting process is being investigated, with preliminary results indicating that thermal shock during the potting process is a large factor in the rejection rate.

Excessive rejections because of defective welds resulted in a corrective action program. A process specification, with metallurgical laboratory backup and operator training and certification, is necessary to eliminate this problem area.

2.10.3.2 SM RCS Rocket Engine

An SM RCS engine failure was shown to be the result of a leakage through the valve with resultant coil shorting, and all shipments were stopped pending failure analysis and corrective action. Disposition of the delivered Spacecraft 009 engines is still pending.

The decrease in I_{sp} reported in the 12th Quarterly Report, SID 62-557-12, and referenced in the 13th Quarterly Report, was resolved. Also, the excessive valve leakage problems reported in the 13th Quarterly Report were resolved.

2.10.4 SUBCONTRACTOR MANAGEMENT

Reliability audits were conducted at both the rocket engine and the propellant quantity gaging supplier's facility in April. Audit results were prepared and are being coordinated within S&ID.

Reliability coordination meetings were held to review acceptance test and qualification test procedures on the SM RCS rocket engine. The subcontractor performed a formal design review on the qualification configuration rocket engine.

2.10.5 TEST PROGRAM

Acceptance testing of the qualification configuration engines is continuing. The acceptance test procedures were reviewed and approved. Qualification test plans and procedures also were reviewed and approved.

Design verification testing of the RCS propellant quantity gaging system is pending demonstration of design maturity. Design verification tests are scheduled to start in August 1965.

2.10.6 PLANNED ACTIVITIES

During the next report period monitoring of specific rocket engine qualification tests and attendance at the design review meeting on the rocket engine is planned. The subcontractor's failure reporting procedures and failure data will be reviewed.

High reliability part specifications for the propellant quantity gaging system and logic diagrams for the Block II system will be completed. Increased qualification test monitoring for the gaging system is anticipated.

2.11 SERVICE PROPULSION

2.11.1 SUMMARY

Supplier acceptance test procedures were reviewed on an accelerated schedule to facilitate hardware acceptance. These specifications were broadened by the addition of reliability requirements governing the continuous, timely, and orderly flow of supplier-prepared failure reports and failure analysis reports.

Requirements of the S&ID Engine Procurement Specification, MC 901-0009G, planned for Block II engine assembly, were strengthened to increase potential mission success probabilities. Considerable effort was expended in the preparation of the S&ID procurement specification for the SPS engine flight combustion monitor.

As a result of intensive research of failure reports, a great number of failure cases were closed. The only cases now remaining open are those in which the subcontractor is delinquent in supplying proper failure analysis.

During integration of the service propulsion subsystem (SPS) into Spacecraft 009, two SPS fuel tanks partially collapsed from depressurization. Recommendations were made for possible design changes and/or procedure changes to help prevent depressurization during network of the propellant feedline. Final solution in this matter is pending.

2.11.2 ANALYSIS

2.11.2.1 Product Mission Analysis

The SPS logic diagram was revised and updated for Spacecraft 009. SPS logic diagrams were prepared for Spacecraft 011 and 012.

The failure mode and effect analysis (FMEA) was revised and updated for Block II SPS fluid system (helium pressurization and propellant distribution). The FMEA for the Block II SPS rocket engine system (pneumatic valve actuation, rocket engine assembly, and engine gimballing) was initiated. This analysis is supported by the FMEA prepared on individual components by the suppliers.

2.11.2.2 Engine Assembly Reliability Sequential Growth Plot

The SPS engine supplier prepared a sequential growth plot based on all engine assembly hot firings through 30 April 1965, including the AEDC firing. This plot indicated a significant improvement in the failure rate of the prototype engine design.

According to the presentation in Aerojet Progress Report for May, 3865-01-34, the engine assembly has 92-percent mission reliability at a 50-percent confidence level and 86-percent mission reliability at a 90-percent confidence level. Detail calculations of this presentation are not available for review at this time.

2.11.2.3 SPS Helium Solenoid Valve and Pressure Regulator Pressurization System

The original FMEA's submitted by the supplier in April were reviewed. The supplier was requested to revise the analyses in accordance with S&ID comments, and to incorporate the design changes required as a result of the design verification tests. The suppliers were furnished S&ID Report SID 64-1447, "Reliability Assessment Guides for Apollo Suppliers," and were requested to submit initial assessments based on design verification test data.

2.11.2.4 SPS Propellant Utilization and Gaging System

At S&ID request, the SPS PUG supplier submitted the report "Approaches of the Incorporation of Solid-State Digital Hardware into the Project Apollo Propellant Utilization and Gaging System." The report, which dealt with several proposed systems for Block II application, was reviewed, and the supplier was requested to supply NAA with more detail information concerning the reliability aspects of the proposed systems.

2.11.3 PROBLEM AREAS

2.11.3.1 Engine Erratic Start and Shutdown Impulse

Previously, specification values for start and shutdown impulse of the engine were not attained because of the erratic opening and closing times of the hydraulically actuated bi-propellant valves. With the recent application of the pneumatic valve actuation system, considerable improvement can be expected. Test results indicate that using a 0.070-inch-diameter opening orifice at the three-way valve inlet part and a 0.100-inch-diameter orifice at the exhaust part will provide the specified valve response time (0.300 to 0.450 seconds). However, closing orifice tests will be continued.

2.11.3.2 Determination of Engine Performance at Altitude

Because vacuum tests were not conducted previously on engines equipped with the prototype configuration (POUL 41-26) baffled injector, it was impossible to predict engine altitude performance from sea-level test data. For this reason, in March and April, engine firing tests were conducted at the Arnold Engineering Development Center to determine engine performance at simulated high-altitude conditions and to obtain minimum impulse data. A baffled injector of the prototype configuration was used in these tests.

2.11.3.3 Gimbal Actuator

In five instances during testing, the gimbal actuator rod end bearing froze. This problem is being eliminated by selection of a proper silicon grease for lubrication. During initial test, the actuator failed to fulfill performance requirements. Subsequently, a new motor pinion was designed, incorporated, and successfully tested. The erratic operation of the magnetic particle clutch is the most serious unsolved problem. Design modifications are in process.

2.11.3.4 Propellant Retention Reservoir

The potential problems of the propellant retention reservoir, their cause, and possible corrective action are shown below:

Problems	Cause	Possible Fix
Helium into propellant flow	Hydrodynamic loadings exceed screen capillary pressure	Increase capillary pressure of screen
Helium bubble from filling operation entering propellant flow	Helium remains trapped in retention reservoir during propellant loading	Provide means to vent all helium out of propellant and retention reservoir during loading
Helium into propellant flow during zero-G condition and during propellant depletion	Zero-G condition	Provide better means to retain propellant within retention reservoir and provide sufficient G load with RCS to settle propellant at tank outlet.
Insufficient flow through umbrella screens during firing	Contamination	Strict enforcement of cleanliness requirements

2.11.3.5 SPS Helium Solenoid Valve

Meetings were held with the helium solenoid valve supplier to emphasize the necessity for timely close-out of failure reports and to clarify the type of detailed analysis and corrective action statements necessary for evaluation of a failure report.

Because of contamination and cleanliness problems, the supplier requested the option of recleaning the valve subsequent to the acceptance test and prior to the cleanliness test. Reliability rejected the request because it would eliminate the cleanliness level check of the cleaning process and acceptance test. If the valve were contaminated during acceptance and, subsequently, cleaned enough to pass the cleanliness test, subsequent problems might result from imbedded contamination working free from crevices during vibration or other applied dynamic forces.

During failure investigation tests on the valve, it was disclosed that the valve could be made to open without the application of current when inlet pressure was applied at a specific increasing rate. This result, caused by the pilot operation of the valve, is being studied for any possible serious effect on system performance.

The supplier experienced numerous failures during the initial design verification test program. These failures are itemized below with a statement of the corrective action applied:

1. Internal leakage during random vibration. Proposed corrective action is a specification change to allow internal leakage as great as 250cc per hour during vibration only.

2. Internal leakage during endurance cycling. Corrective action included Teflon impregnation in lieu of lubricant at the static seal, and machine lap in lieu of polish on the pilot ball surface. A method of Teflon wear-in was substituted for the grease-type contaminant used on the static-seal O-ring and the KEL-F pilot seat. Valve cleaning procedures were revised to reduce induced and generated contamination.

3. Failure to meet dielectric strength and insulation resistance requirements. Corrective action included improving the technique of mechanically anchoring the wires into the potting, and looping and securing the wire bundle to the solenoid body so that flexing of the wires causes no damage. The required voltage for insulation resistance and dielectric strength tests was reduced.

2.11.3.6 SPS Helium Pressure Regulator

During Spacecraft 009 checkout, an instability of regulation was noted. This was attributed to the use of an extremely large ullage volume and check-valve chatter. However, a failure investigation test is being performed by the supplier to determine the exact cause of the pressure oscillations.

Design improvements, including an internal pressure surge arrestor and filter, are being incorporated in a Block II procurement specification for the regulator. The necessity for propellant compatibility of the regulator has not definitely been proven. The procurement specification will require additional design verification and qualification testing.

2.11.3.7 SPS Relief Valve

Prior to the installation of a surge arrester in the SPS feed system of Spacecraft 009, several relief valve burst diaphragms were ruptured. This was attributed to the pressure surges caused by the operation of the helium solenoid valves. No diaphragm rupture has been reported since a surge arrester and orifice was installed upstream of the regulator.

2.11.4 TEST PROGRAM

2.11.4.1 SPS Engine Assembly and Components

During this reporting period, the following SPS engine assembly and component tests were conducted: dynamically stable injector development tests, thrust chamber assembly development tests and sea-level engine development tests, engine testing at simulated high altitudes, in-house qualification injector tests, sea-level engine acceptance tests, gimbal bearing assembly tests, strut assembly and thrust mount assembly, propellant line assembly and filter screen assembly, gimbal actuator, pneumatic package and pneumatic valve assembly, and electrical harness.

2.11.4.2 Propellant Utilization and Gauging System

Developmental testing continued during this reporting period. Propellant compatibility tests were performed on components and subassemblies, and a development test program was run on various valve configurations. Valves with unplated gates, chrome-plated gates, and Teflon-coated gates were subjected to a series of tests to investigate friction and cycling effects. The results of the tests dictated the use of the Teflon-coated configuration. Accuracy checks on the fuel and oxidizer sensors were also conducted with satisfactory results.

2.11.5 SUBCONTRACTOR MANAGEMENT

A reliability audit was conducted at the helium pressure regulator supplier (B.H. Hadley) on 16 April 1965. The audit report directed the supplier to submit revisions of the FMEA, apportionments, predictions and logic and to submit an initial reliability assessment based on design verification test data. The prediction was to reference failure rates and show ability to meet the required reliability goal. The audit report also required that the supplier conduct a formal design review and maintain status and disposition of action items.

A reliability audit of the propellant utilization gauge supplier was conducted during this reporting period. The supplier was given the results and is making the recommended program corrections.

2.11.6 PLANNED ACTIVITIES

During the next quarter, the subcontractor's specifications and reports will be reviewed and the reliability requirements strengthened for Block II vehicles.

A thorough investigation will be made of all problems and efforts will be made toward their elimination.

Increased monitoring of supplier testing and surveillance of the overall supplier's reliability programs are planned for the next reporting period.

3.0 SPACECRAFT ELECTRONICS

3.1 ANTENNAS, RF AND VIDEO COAXIAL CABLES AND CONNECTORS

3.1.1 SUMMARY

The major effort for the quarter involved the initiation of qualification test programs on new equipment, the investigation of problem areas and failures of coaxial cables and connectors, and the monitoring of supplier reliability programs.

3.1.2 PROBLEM AREAS

3.1.2.1 RF Coaxial Push-on Type Connectors, (TNC and HN Series)

The failure modes and problems on the Stoddart connectors reported in the thirteenth quarterly report were not completely eliminated; however, a quality control survey was performed, and close surveillance of the manufacturing was instituted. A second source supplier is being acquired for Block II hardware.

3.1.2.2 Video Coaxial Connectors

The retest of the humidity-oxidation-salt spray portion of the qualification tests for the AMP connector procured to MC 414-0165 was successfully completed on 15 March 1965. This test and a subsequent functional test completed the qualification program for these connectors.

3.1.2.3 RF Coaxial Connectors, (Types CX, HN, and TNC)

The ITT/Cannon CX connector procured to MC 414-0345 is being redesigned to captivate the center conductor in both directions. Thermal cycling development tests are revealing problems with the HN and TNC connectors. Analysis attributed the primary cause of failure to cable expansion and contraction. An investigation of procurement of cable that can meet Apollo requirements was implemented.

3.1.2.4 RF Coaxial Switch

Redesign of the VHF and 2-kmc switches to eliminate several of the failure modes and improve the reliability of the parts was accomplished by Transco Inc. The Agena-type hermetically sealed switch will be used on Block I and II manned vehicles.

3.1.3 PLANNED ACTIVITIES

Acceptance and qualification tests on the VHF/2-kmc scin antenna (S&ID) and the Littleton/Amecom C-band anntenna will require reliability monitoring. Areas of concern are vibration, acoustics, altitude/high power, and thermal shock tests.

Close surveillance of Dalmo Victor's procurement and control practices will be required to verify that parts for the earth sensor and servo electronics are of demonstrated high reliability.

Stoddart Electro Systems will require close surveillance during their entire qualification program. The qualification test schedule continues to slip because of numerous failures in acceptance testing.

Continuing connector-cable interface problems at ITT/Cannon during development testing make qualification test surveillance advisable.

Design reviews and test program activity approval of DeHavilland HF recovery and orbital antennas are scheduled for the next quarter.

The development of the high-gain antenna subassembly by Dalmo Victor will be closely monitored, with special attention paid to qualification of the parts for Apollo application. An informal design review at the subcontractor's facility on 16 June 1965 will be attended.

3.2 AUTOMATED SYSTEMS

3.2.1 SUMMARY

Those portions of the P103 mission control programmer (MCP) that interface with the Spacecraft 011 guidance and control (G&C) function were included in the FMEA for Spacecraft 011 guidance and control. Revisions to the attitude reference system and P103 mission control programmer procurement specification were reviewed and approved. The relay problem on the P100 control programmer was resolved.

3.2.2 ANALYSIS

The portions of the Spacecraft 011, P103 mission control programmer that functionally interface with the G&C equipment were incorporated into the FMEA for Spacecraft 011 G&C. No problems are evident from this analysis.

Requalification of the control programmer relays was accomplished without failure. A review of the adequacy of the Babcock relays to meet all the high reliability requirements was made. The relay was found to be acceptable and will be used in the P100 for Spacecraft 009 (See 2. 3. 3. 7).

3.2.3 SUBCONTRACTOR MANAGEMENT

A design review of the control programmer was held at Autonetics on 7 May 1965. No problem areas affecting reliability were discovered.

Revisions to the attitude reference subsystem (ARS) and the P103 mission control programmer procurement specifications were reviewed. Both documents were approved. The ARS revision pertained to increased qualification test requirements in the areas of vibration and acceleration. The MCP revision included changes to performance requirements.

Review of parts to be utilized in the P103 mission control programmer resulted in the discovery of commercial parts in the Parco time delay. Autonetics was notified that commercial parts are unacceptable, and Autonetics notified Parco to procure high reliability parts for incorporation into time-delay circuits. No problem pertaining to schedule is associated with this requirement.

3.2.4 PLANNED ACTIVITIES

Qualification testing of the attitude reference system will be performed during the next quarter, and it is anticipated that the prime effort will be the monitoring of the testing.

3.3 COMMUNICATIONS

3.3.1 SUMMARY

The major effort during this reporting period included completion of a FMEA on Spacecraft 011, further investigation of the transistor and silicon control rectifier failures, and review of acceptance and qualification test procedures.

3.3.2 ANALYSIS

The current reliability predictions for the equipment furnished by Collins Radio Company are summarized in Table 3-1. These were updated as additional failure rates became available and actual stress levels were determined by the parts application tests.

Table 3-1. Communication Equipment Reliability Prediction Summary

Equipment	Apportionment	Prediction
VHF/AM transmitter-receiver	0.9990	0.9986
VHF recovery beacon	0.99981	0.99991
HF transceiver	0.99972	0.99990
VHF/FM transmitter	0.99996	0.99984
Audio center	0.9969	0.9977
Premodulation processor	0.9967	0.99672
Signal conditioning equipment		
Phase-sensitive demodulator	0.99864	0.999507
Frequency-sensitive demodulator	0.99853	0.999505
DC amplification	0.99858	0.999401
AC-DC conversion	0.99861	0.999490
DC attenuation	0.99894	0.999568
10-vdc power	0.99954	0.999764
5-vdc power	0.99954	0.999764
S-band power amplifier	0.9969	0.9979
PCM telemetry equipment	0.9630	0.9847
Data storage equipment	0.9930	0.99550
C-band transponder	0.9995	0.9991
Unified S-band equipment	0.9954	0.993

3.3.2.1 Logic Diagrams and Failure Mode and Effects Analysis

The Spacecraft 011 logic diagrams and FMEA were completed; Spacecraft 012 logic diagrams and FMEA are 50 percent complete and are scheduled for completion during the next reporting period.

3.3.2.2 Pulse Code Modulation Diode Programmer Matrix and Control Circuitry

A computerized worst-case analysis was performed on the subject circuitry to determine if there were over-stressed conditions for all circuit piece parts, as well as the General Instrument and Texas Instruments transistors that had previously failed. All worst-case stress solutions were compared with their maximum values; the results of the analysis indicated that these stress levels were considerably short of the maximum ratings for all resistors, diodes, and transistors. Therefore, based on the satisfactory stress ratios, no design changes were recommended.

3.3.2.3 Computerized Stability Analyses of Apollo Communication System Regulated Power Supplies

A computerized analysis, using the SCAN ACI frequency analysis techniques, was performed on the Collins Radio (CRC) power supplies. The results showed the +5, +10, +20 and -20 volt signal conditioning equipment power supplies to be dynamically stable, while inherent instability was indicated in the computerized Bode plot for the premodulation processor power supply. The dynamic instability of the power supply regulating amplifier is considered a critical first-order failure mode because of the dynamic operating range of the power supply. The condition could be corrected by using a double-phase lead compensation network in the vicinity, before the crossover point of 220 kc. This was recommended.

3.3.3 PROBLEM AREAS

Considerable effort was expended on transistor failure analysis and the associated investigation and corrective action. Details of these failures and the associated problems were discussed with representatives of Bell Telephone Laboratories and Bell Comm, representing NASA.

3.3.3.1 Silicon Control Rectifier

This part (ACFE PN 050801) is used in the C-band transponder manufactured by ACF Electronics as part of the communications and data subsystem. The part is similar to the commercial SCR-75. It is manufactured solely by Motorola Semiconductor Division. Eighty-five qualified units are required to meet equipment commitments. The part vendor has been unable to manufacture an acceptable lot (low yield) in over eighteen months (lot 9 recently failed). The difficulty is associated with the amount of gold diffusion added to the silicon. The process is critical to the electrical characteristics. Numerous alternate plans are in process but no definite solution has been reached.

3.3.3.2 Transistor, Texas Instruments 3N74

Texas Instruments 3N74 transistor, used in the PCM telemetry equipment built by Radiation, Inc. as part of the communications and data subsystem, failed during in-process testing at the submodule level. Analysis of the failure disclosed open bonds between the gold wire and either the emitter or the base elements. An extensive investigation did not disclose the failure mechanism. Environmental tests were rerun in an attempt to duplicate the failure; all were unsuccessful including the tests at environmental levels in excess of those required during qualification. The total stock was rescreened, a fabrication change incorporated, and the process controls tightened as the major part of the corrective action. The total quantity of parts on hand was 13,000, leaving the percentage of failures (0.046 percent) relatively insignificant. The failure effects evaluation and the results of the environmental tests are considered adequate to justify the continued use of the part for Apollo, and the failure will be classified as random. No additional failures have been reported since the rescreening was completed. The type of failure mode (open bond) makes detection of failure before final acceptance a certainty, and environmental stresses after acceptance are negligible in comparison to the part acceptance test levels.

3.3.3.3 Transistor, General Instruments

Three general purpose transistors used in the PCM telemetry equipment, failed with open bonds (lead-to-element) during in-process tests at the submodule level. There are 423 of these transistors used in each PCM equipment. Approximately 10,000 parts (including stock) were rescreened. Investigations and exploratory tests failed to determine the cause of failure, but it was concluded that the vendor did not exercise adequate process controls during fabrication of these parts. Since over 400 devices were subjected to environments in excess of any expected during use without duplication of the failure mode, the device is considered qualified, and the failures classified as random. Corrective action consisted of tighter fabrication controls, rescreening all devices at the part, module, and black-box level, and selection of an alternate source for use on Block II equipment. No additional failures have been reported to date.

3.3.3.4 Transistors, Amelco (All Units)

Several transistor failures on Amelco parts were reported. The failure mode was circuit shorting caused by metal slivers that remained in the transistor can after the cleaning process. The investigation to date disclosed an inadequate cleaning process being utilized by Amelco.

Screening or rescreening methods are not 100 percent effective in removing contaminated transistors. The only effective corrective action is to eliminate the failure mechanism by an effective can cleaning process. This process has been established and specifications revised to implement in all future parts procurements.

In a meeting between the NASA, NAA, and CRC, it was decided to retrofit at the earliest available date, and the investigation will continue on this failure problem to determine the failure effects for each application and the probability of recovery from an intermittent short.

3.3.4 TEST PROGRAM

3.3.4.1 Qualification Test Procedures

The third submittal of Collins Radio qualification test procedures (QTP) for the audio center and S-band power amplifier were conditionally approved. It is expected that the QTP's for the remaining equipment will be approved by 1 July 1965.

3.3.4.2 Acceptance Test Procedures

The eleven acceptance test procedures were either approved or conditionally approved during this reporting period.

3.3.5 SUBCONTRACTOR MANAGEMENT

A reliability audit was performed at Collins Radio during this reporting period. Significant items resulting from the audit are as follows:

1. Reliability indoctrination and training is a minimal effort. There is, however, a zero-defects program covered by the Quality Assurance Group.

2. Reorganization within the company has spread Reliability manpower over the Apollo contract and the LEM contract. The effect of this on the Apollo Program remains to be examined.

3. Reliability participation in the test program has been inadequate to assure an overall well-integrated test program, with utilization of test data from all areas of testing. Reliability has primary responsibility for only the mission life test. No plans exist for utilization of tests or test data for an analytical assessment of reliability or verification of the reliability predictions for equipments of the C&D subsystem.

4. Concerted effort on the failure reporting and feed-back system reporting requirements and the improvements in the reporting were noted during the audit. This effort was required prior to the audit as a result of repeated delinquency in meeting the established reporting requirements.

3.3.6 PLANNED ACTIVITIES

The qualification test procedures will be approved and the testing started. Portions of the qualification tests will be monitored.

Block II logic diagrams will be revised to include all displays and controls and to conform with the latest equipment configurations. The logic diagrams, single-point failure summaries, and FMEA's will be completed for Spacecraft 012, 014, 017, and 020.

3.4 DATA SYSTEMS

3.4.1 SUMMARY

Effort was expended during the reporting period on reliability audits, Block II specifications, mission success logic diagrams, and FMEA reports.

3.4.2 ANALYSIS

Analysis effort supporting Spacecraft 002, 009, 010, 011, and 012 included:

1. Logic diagrams (preliminary) for Spacecraft 011, 012, and 009 (updated)

2. Single-point failure summary (preliminary) for Spacecraft 009 (updated), 011, and 012 (in process)

3. FMEA's for Spacecraft 011 and 012 (in process, 50 percent complete)

4. Minimum airworthiness requirements and status for Spacecraft 009 (updated) and 002 (completed)

3.4.3 PROBLEM AREAS

3.4.3.1 General Instrument Company Transistors

General Time (GT) used large quantities of General Instrument Company (GI), 2N914 transistors for the central timing equipment (CTE), pending delivery of the Texas Instrument (TI) transistors approved by NAA in the non-standard parts list. Since other types of GI transistors experienced bond failures, General Time was directed to halt procurement of GI transistors. The use of GI transistors is restricted to redundant circuits, except in the one-pulse-per-ten-minute output from the CTE.

3.4.3.2 McCoy Crystals

Crystals that contained welds made without process control specifications were delivered by McCoy Electronics Company to General Time Corporation (GT) for use in the CTE. These welds are at the junction of the stainless steel crystal support and the Kovar pins in the base of the holder.

Examination of 29 crystals at GT revealed the presence of small droplets, or balls, of expulsed weld metal attached to the Kovar pins and/or stainless steel supports on or near the weld area. The balls could become dislodged during use and cause failure. In an effort to evaluate this condition, GT X-rayed ten samples received from McCoy, and all ten exhibited the questionable condition. Six of the ten were subjected to vibration normal to the plane of the crystal wafer and X-rayed again; none of the weld balls were dislodged. The balls were probed to evaluate the degree of bonding. Dislodging required a 5- to 8-pound force on 4 samples; six could not be dislodged. Some welds were subjected to a pull test, breaking only after loads far in excess of any flight requirements; others were examined metallographically and showed an acceptable microstructure.

Collins Radio Company uses these crystals in the following units: VHF-AM, HF, PCM, C-band, and unified S-band equipment. Three types of holder are used. Qualification tests have been performed on a total of 160 of these types of crystal. Forty units were subjected to sine wave vibration and shock, and ten to random vibration, shock, and acceleration. No failures were encountered in the shock and vibration tests because of faulty welds of the crystal mount holder-to-holder pin resistance weld connections.

S&ID directed GT to use the following criteria for acceptance of support welds in the crystals for the CTE..

1. Crystals must be qualified in accordance with GT Specification 7110001.

2. Balls of expulsed weld material must not be greater than 1/32-inch diameter.

3. Contact area of balls must have a width that exceeds fifty percent of the diameter of the ball, with the following exception: the crystals may be used if the ball position does not change after one sweep of vibration to the levels of Specification 7110001.

For Block II, Collins Radio is assisting McCoy with the preparation of a weld schedule to eliminate the expulsed weld material.

3.4.4 SUBCONTRACTOR MANAGEMENT

3.4.4.1 General Time Corporation

General Time Corporation is updating the reliability program plan under new management. The new program plan is based upon S&ID requirements, and the new management has placed the Reliability section in a more favorable position. Improvements are still needed in the areas of failure reporting and corrective action and of parts and material selection.

3.4.4.2 Leach Controls

Although no contractual deficiencies were noted in the audit, it was recommended that the company be made aware that unnecessary problems could result from lack of formal internal documentation.

3.4.4.3 Motorola

The audit of Motorola showed that the reliability tasks are performed by two organizations, the Reliability and Components Group during the early phases of the program and the Quality Assurance Group during the remainder of the program. The results obtained by this organizational structure at Motorola have been generally good; the only noted problem area was associated with data retrieval.

3.4.4.4 RCA

The reliability program at RCA is proceeding in a satisfactory manner. Only limited reliability requirements are imposed by specifications, and these are being met. No corrective action was required as a result of the reliability audit. This contractor is not involved with the Block II TV camera.

3.4.5 PLANNED ACTIVITIES

During the next quarter, logic diagrams, FMEA's, and single-point failure summaries will be updated for Spacecraft 012 and 008, in addition to preparation of preliminary logic diagrams, FMEA's, and single-point failure summaries on Spacecraft 014, 017, and 020. Considerable subcontractor/supplier coordination effort will be expended on Block II reliability programs. Particular attention will be given to parts selection and qualification. Monitoring will start on end-item qualification tests.

3.5 DISPLAYS AND CONTROLS

3.5.1 SUMMARY

Reliability efforts have been concentrated on qualification tests for Block I components and the initial steps for Block II. Suppler qualification testing is either in progress or scheduled to begin within the next quarter.

3.5.2 ANALYSIS

The preliminary FMEA for displays and controls were completed. These analyses will be expanded and integrated into each of the various spacecraft subsystem FMEA. FMEA for units (floodlights, clocks, timers, G-Meter, altimeter, etc.) that do not become part of other subsystems are complete and awaiting approval.

Reliability failure cause analyses, were performed on the toggle switch, rotary switch, push-botton switch, and the circuit breaker. Suggested corrective actions are being discussed with the suppliers. As a result of these analyses and development failures, additional analysis and monitoring requirements will be necessary.

Proposals for design of the command module integral panel lights and floodlights were reviewed and evaluated. The proposed design requires adaptation of designs which were not extensively used in previous space programs. Therefore, extensive development effort to achieve life requirements and a well-developed reliability program will be required. Discussion and investigation of supplier facilities were required to assure that a suitable reliability effort would be expended.

Proposals on the variable transformer and the two types of event indicators for Block II (solid-state and electro-mechanical with electro-luminescent) are being evaluated.

3.5.3 TEST PROGRAM

Supplier acceptance test and qualification test procedure revisions were reviewed. The detailed qualification test procedures for the display and control panels are in process.

Qualification testing for Block I is in progress on the following units:

Unit	Manufacturer
Event indicator	Grimes
Annuciator	Grimes
Toggle switch	Microswitch Division
Event indicator	Weston
Electrical meters	Weston

3.5.4 PROBLEM AREAS

There are no open test failures.

3.5.5 SUBCONTRACTOR MANAGEMENT

Reliability audits were performed at the following subcontractors: Gibbs (digital event readout timer, clocks, and timer supplier); Microswitch (toggle-switch supplier); Mechanical Products (circuit breaker supplier); Daven (rotary-switch supplier); Weston (meter and event indicator supplier); and Grimes (event indicator and annunciator supplier). Discrepancies identified by these audits, primarily failure reporting and inadequacies, are being corrected.

The potentiometer manufactured by Technology Instrument Coporation was redesigned to replace the binding post terminal with a solder-type terminal. This eliminated the Epon material around the terminal that was collecting moisture and creating dielectric breakdown.

Reliability monitored portions of the annunciator, event indicator, and toggle switch qualification tests that were performed at the Environmental Test Laboratory in Minneapolis, Minnesota. As a result, schedule compliance by the suppliers and the respective test laboratories is being improved.

3.5.6 PLANNED ACTIVITIES

During the next quarter, requested acceptance test and qualification test revisions will be reviewed. Initial acceptance test and qualification test procedures on the floodlights and the G-meter are required for review.

Scheduled qualification tests will be monitored, and additional Block II proposals will be evaluated.

The design review of the displays and controls is scheduled for the next reporting period.

3.6 GUIDANCE AND CONTROL

3.6.1 SUMMARY

During this reporting period, emphasis was placed on the Block I spacecraft integrated guidance and control electronics analysis. Updated Block II logic was initiated. A study on an alternate mode of operation for performance of backup Guidance Navigation and Control (GN&C) and Stabilization and Control Subsystem (SCS) functions was completed.

3.6.2 ANALYSIS

3.6.2.1 Logic Diagrams

Updated Spacecraft 011 logic diagrams were completed and are being coordinated with Guidance and Control Engineering to identify all interrelationships between stabilization and control, guidance and navigation, controls and displays, and the mission control programmer. A detailed analysis was completed on the mission control programmer to identify each separate functional relationship with the GN&C and SCS. Figures 3-1 through 3-13 illustrate the updated Spacecraft 011 guidance and control mission success reliability logic. (All relay contacts shown on the reliability logic charts are components of the mission control programmer.)

The preliminary combined electronic subsystem reliability logic diagrams have been completed for Spacecraft 006 and 012. Because Spacecraft 006 is similar to Spacecraft 012, the same diagrams are being used.

The updated Block II logic diagrams have been initiated for the combined guidance and control electronics and telecommunications. This effort will be completed early in the next quarter.

3.6.2.2. Failure Mode and Effects Analysis

The Spacecraft 011 FMEA was initiated and will be completed within the next quarter. From this FMEA, the single-point failure summary will be updated, as applicable.

The preliminary Spacecraft 012 FMEA was completed for the guidance and control subsystems.

3.6.2.3 Single-Point Failure Summary

The updated Spacecraft 011 single-point failure summary for the guidance and control subsystems was completed and is being coordinated with Engineering. The attitude control electronics within the stabilization and control subsystem exhibit the majority of the potential failure modes. Maximum output from these electronic packages could cause loss of the spacecraft if telecommunications are lost during the entry phase of the mission.

The preliminary single-point failure summary for Spacecraft 006 and 012 has been completed for all guidance and control electronic equipments and has been reviewed by Design Engineering.

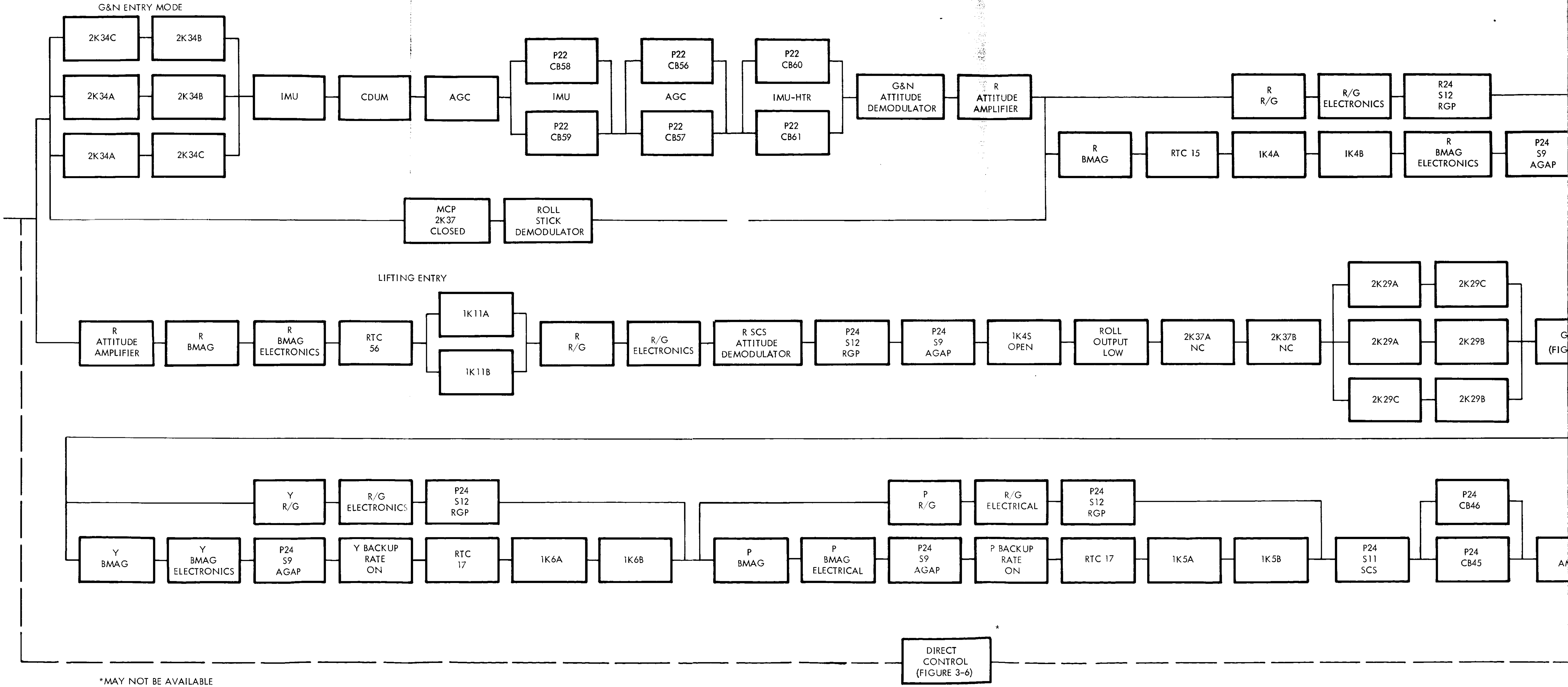
3.6.2.4 Worst-Case Analysis

A computed worst-case analysis was performed on the D-C amplifier-demodulator and the modulator servo-amplifier to determine stress conditions on various components. All component stresses on the d-c amplifier-demodulator fell below the maximum ratings, and a resistor in the modulator servo-amplifier was overstressed by 148 percent. The absolute maximum stress rating is 125 milliwatts, and the computed worst-case stress was 186.5 milliwatts. Therefore, it was recommended that the resistor be changed to reflect a maximum stress rating of 250 milliwatts.

3.6.2.5 Block I Crewman's Optical Alignment Sight Back-Up Modes Study

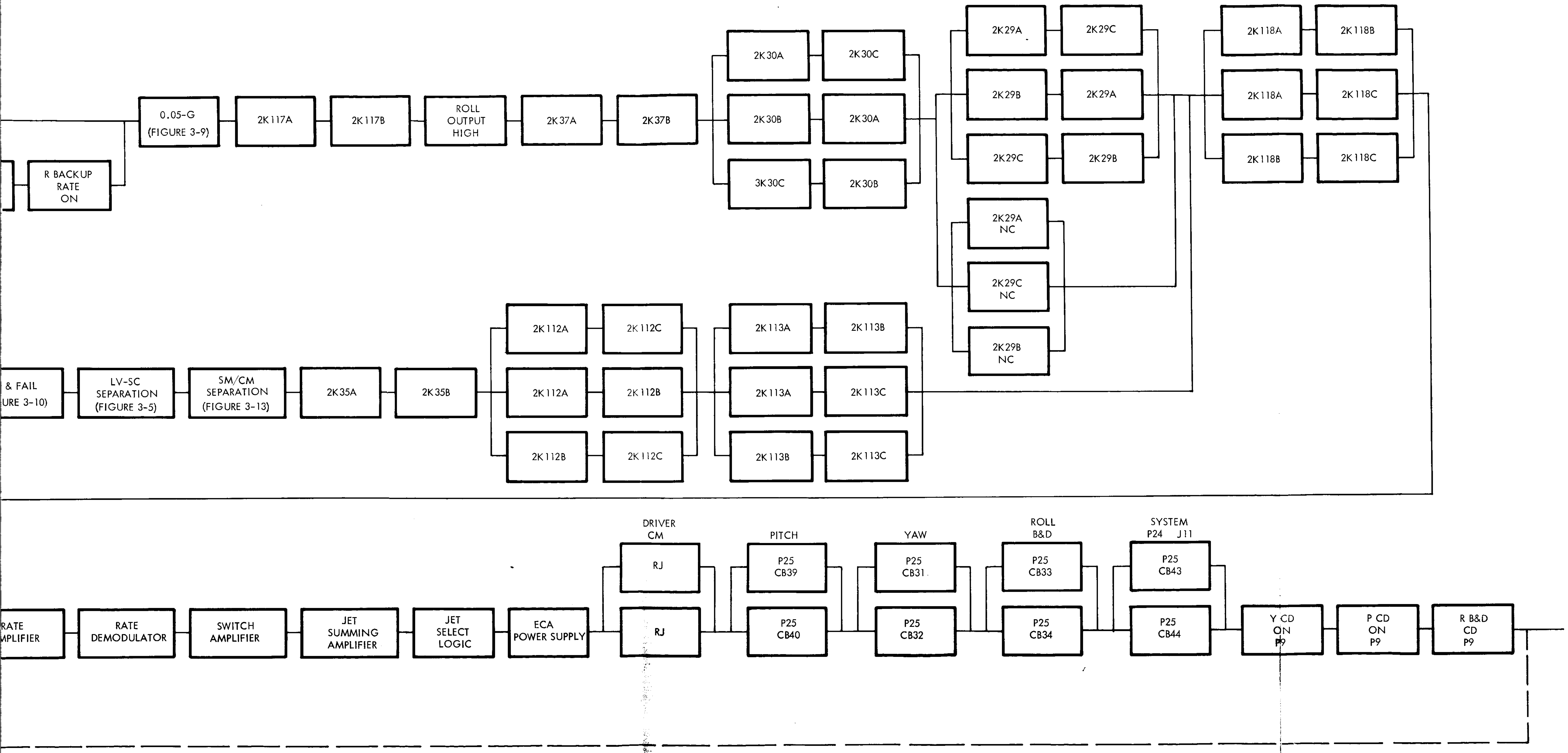
Reliability requirements analyses for Apollo Block I manned vehicles indicated that an alternate mode of operation is necessary for the performance of back-up GN&C and SCS functions to meet specified objectives. Test objectives specified in the NASA Program Initial Mission Directives (IMD) for Spacecraft 012 (A-204) require GN&C and SCS equipment operating times that exceed constraining values imposed to meet overall mission success probability requirements of 0.9785 established in conformance with the NASA directives, letter PR-65-354.

The backup mode study was performed with the employment of reliability logic diagrams. These logic diagrams delineated a suboptimization of equipment configurations yielding the most effective results. These diagrams also contained equipment failure rates and operating times for Spacecraft 012 (A204) and represented operations with and without a COAS. In addition, operating times were included in the analysis to represent possible worst-case conditions for certain SCS equipment which may be required to operate for extended periods throughout the mission for optimum spacecraft thermal equilibrium control.



*MAY NOT BE AVAILABLE

FOLD-OUT #1

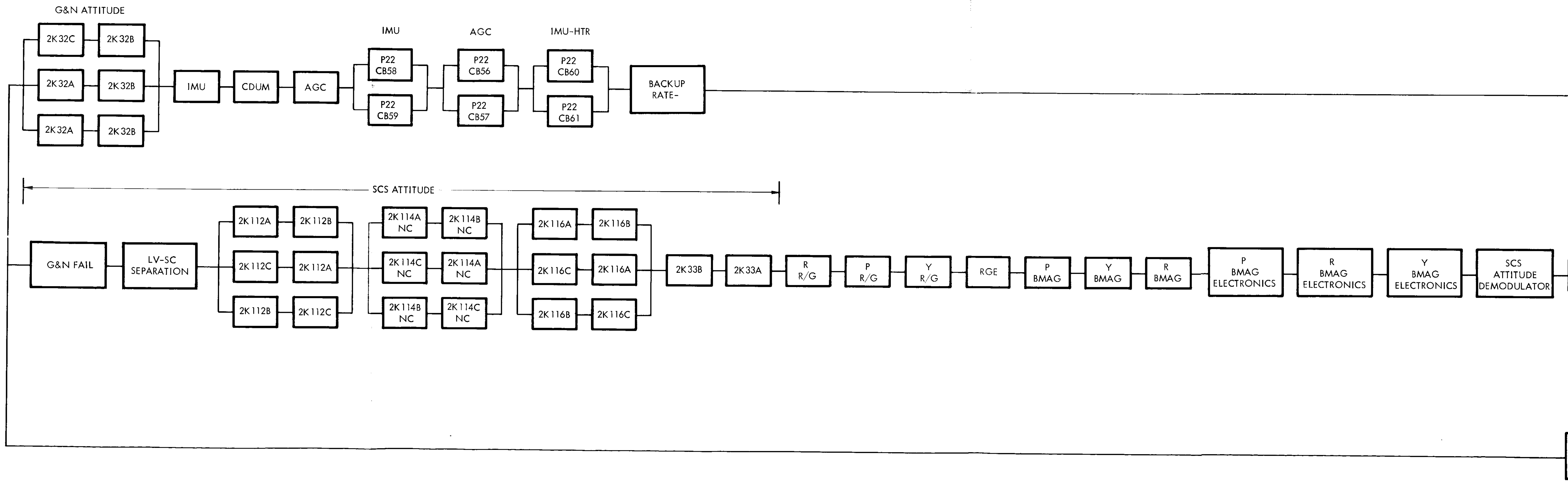


NOMENCLATURE

AGAP	ATTITUDE GYRO ACCELEROMETER PACKAGE
AGC	APOLLO GUIDANCE COMPUTER
BMAG	BODY-MOUNTED ATTITUDE GYRO
CB	CIRCUIT BREAKER
CD	CHANNEL DISABLE
CDUM	COUPLING DISPLAY UNIT, IMU
ECA	ELETRONICS CONTROL ASSEMBLY
HTR	HEATER
MCP	MISSION CONTROL PROGRAMMER
NC	NORMALLY CLOSED
P	PITCH
R	ROLL
R/G	RATE GYRO
RJ	REACTION JET
RTC	REAL TIME COMMAND
Y	YAW

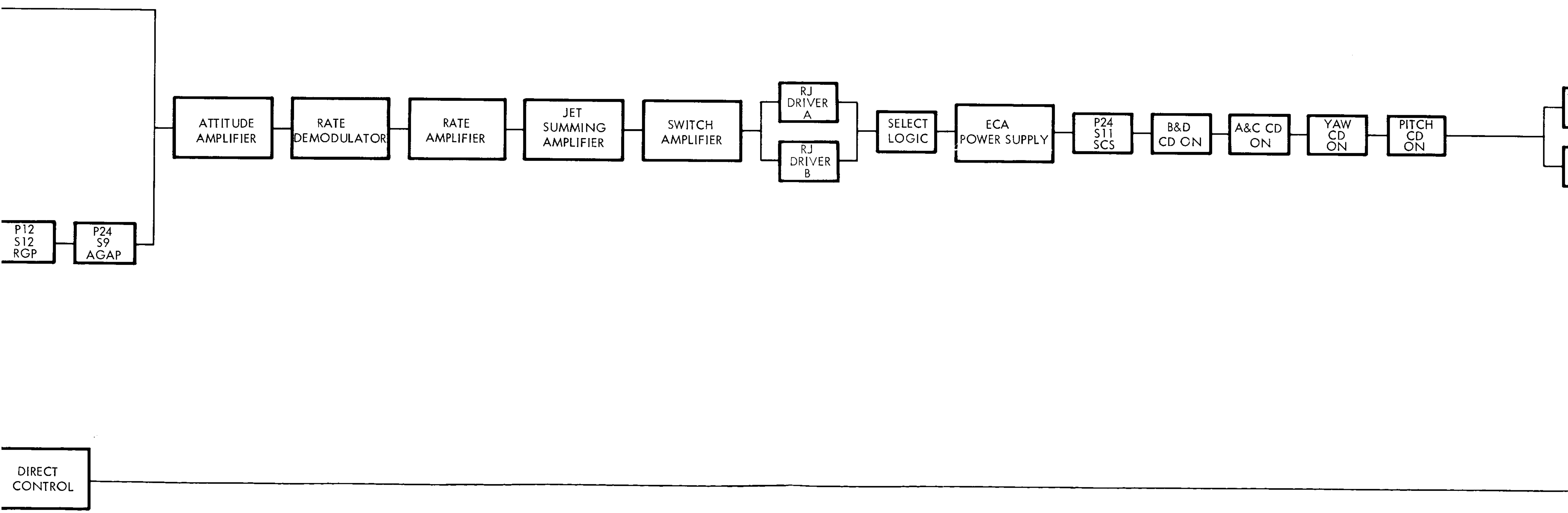
Figure 3-1. Entry Mission Success Logic Diagram, Spacecraft 011

FOLD-OUT #2



G&N ATTITUDE
2K32C
2K32B
2K32A
2K32B
2K32A
2K32B
IMU
CDUM
AGC
IMU
P22 CB58
P22 CB59
AGC
P22 CB56
P22 CB57
IMU-HTR
P22 CB60
P22 CB61
BACKUP RATE-
SCS ATTITUDE
G&N FAIL
LV-SC SEPARATION
2K112A
2K112B
2K112C
2K112A
2K112B
2K112C
2K114A NC
2K114B NC
2K114C NC
2K114A NC
2K114B NC
2K114C NC
2K116A
2K116B
2K116C
2K116A
2K116B
2K116C
2K33B
2K33A
R R/G
P R/G
Y R/G
RGE
P BMAG
Y BMAG
R BMAG
P BMAG ELECTRONICS
R BMAG ELECTRONICS
Y BMAG ELECTRONICS
SCS ATTITUDE DEMODULATOR

FOLD-OUT #1

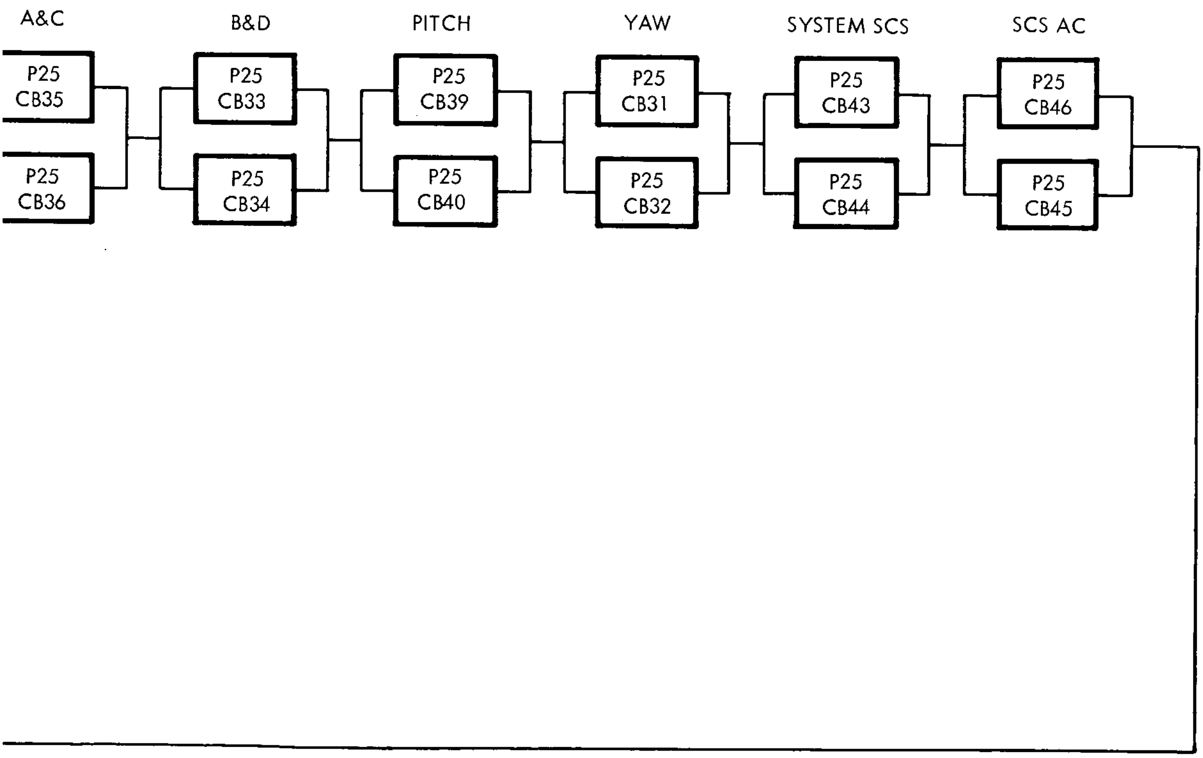


FOLD-OUT #2

Fig

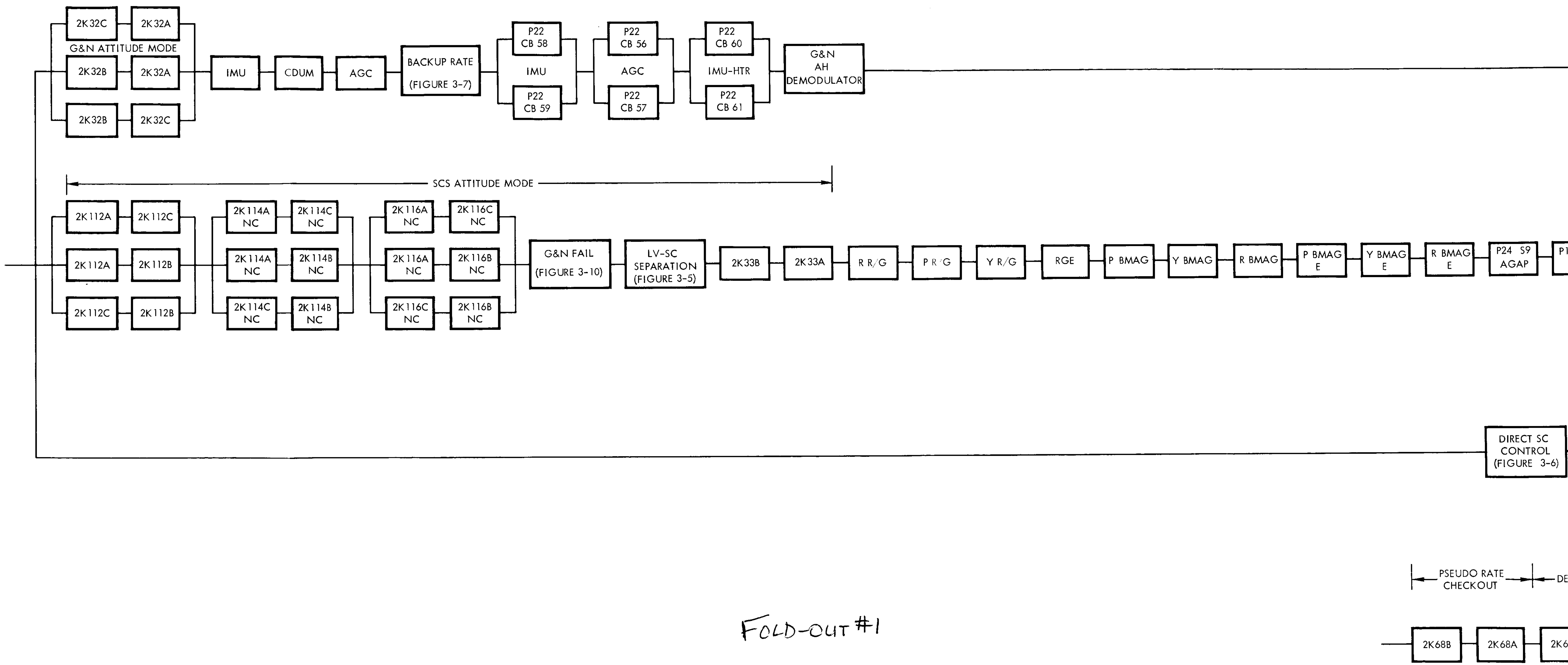
NOMENCLATURE

AGAP	ATTITUDE GYRO ACCELEROMETER PACKAGE
AGC	APOLLO GUIDANCE COMPUTER
BMAG	BODY-MOUNTED ATTITUDE GYRO
CB	CIRCUIT BREAKER
CD	CHANNEL DISABLE
CDUM	COUPLING DISPLAY UNIT, IMU
ECA	ELECTRONICS CONTROL ASSEMBLY
IMU	INERTIAL MEASUREMENT UNIT
P	PITCH
R	ROLL
R/G	RATE GYRO
RGE	RATE GYRO ELECTRONICS
RGP	RATE GYRO PACKAGE
RJ	REACTION JET
Y	YAW

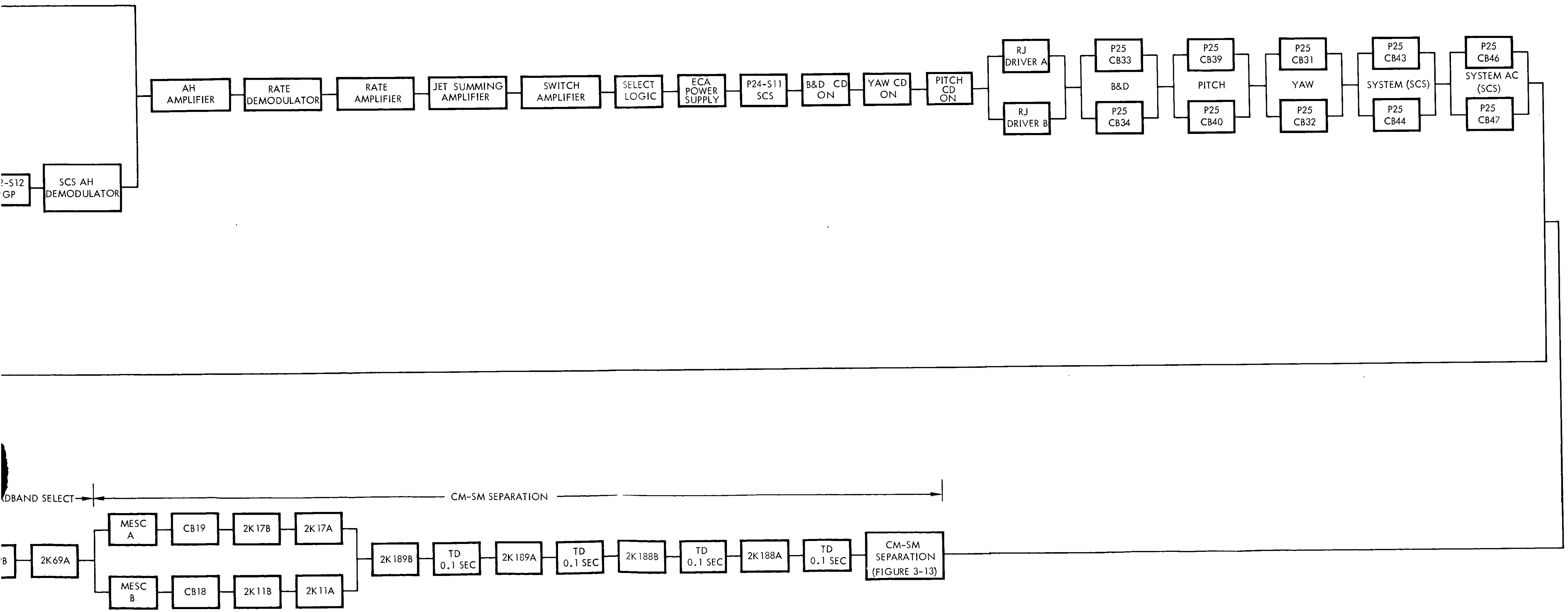


FOLD-OUT #3

ıre 3-2. Attitude Control Mission Success Logic Diagram, Spacecraft 011


2K32C
2K32A
G&N ATTITUDE MODE
2K32B
2K32A
2K32B
2K32C
IMU
CDUM
AGC
BACKUP RATE
(FIGURE 3-7)
P22
CB 58
IMU
P22
CB 59
P22
CB 56
AGC
P22
CB 57
P22
CB 60
IMU-HTR
P22
CB 61
G&N
AH
DEMODULATOR
SCS ATTITUDE MODE
2K112A
2K112C
2K112A
2K112B
2K112C
2K112B
2K114A
NC
2K114C
NC
2K114A
NC
2K114B
NC
2K114C
NC
2K114B
NC
2K116A
NC
2K116C
NC
2K116A
NC
2K116B
NC
2K116C
NC
2K116B
NC
G&N FAIL
(FIGURE 3-10)
LV-SC
SEPARATION
(FIGURE 3-5)
2K33B
2K33A
R R/G
P R/G
Y R/G
RGE
P BMAG
Y BMAG
R BMAG
P BMAG
E
Y BMAG
E
R BMAG
E
P24 S9
AGAP
DIRECT SC
CONTROL
(FIGURE 3-6)
PSEUDO RATE
CHECKOUT
2K68B
2K68A

FOLD-OUT #1

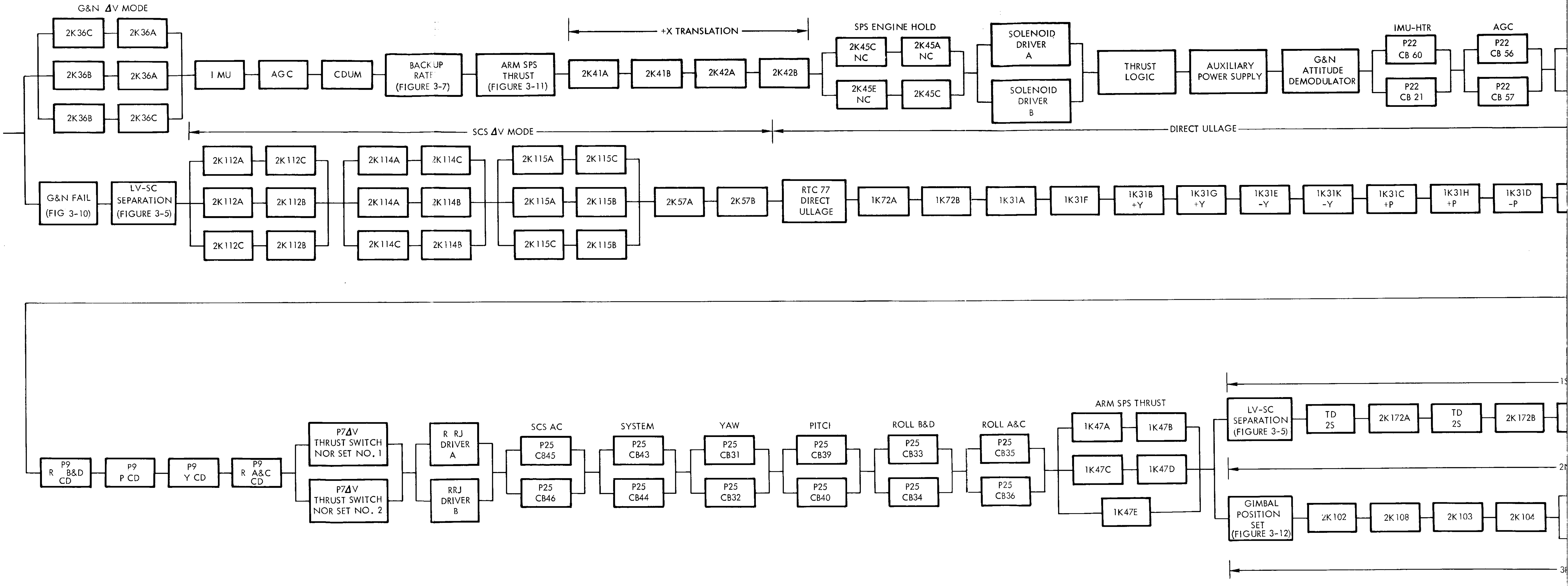


NOMENCLATURE

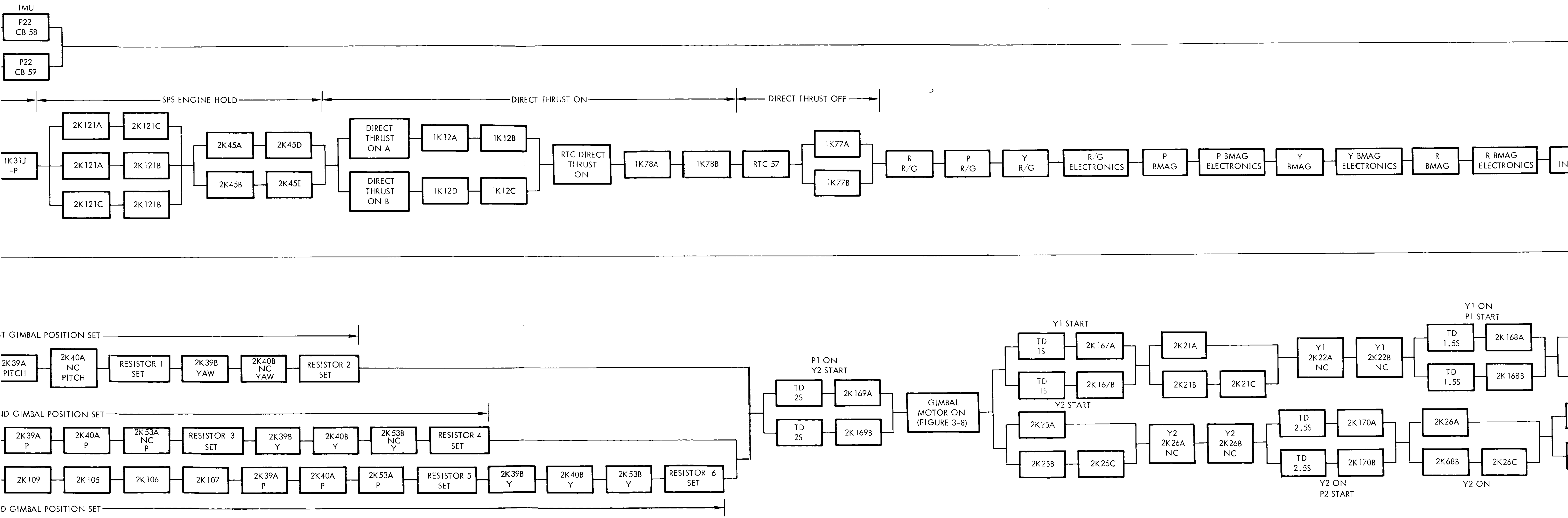
AGC	APOLLO GUIDANCE COMPUTER
AH	AMPERE - HOUR
BMAG	BODY-MOUNTED ATTITUDE GYRO
CB	CIRCUIT BREAKER
CDUM	COUPLING DISPLAY UNIT, I MU
ECA	ELECTRONICS CONTROL ASSEMBLY
HTR	HEATER
IMU	INERTIAL MEASUREMENT UNIT
MESC	MISSION SEQUENCER
NC	NORMALLY CLOSED
P	PITCH
R	ROLL
R/G	RATE GYRO
RGE	RATE GYRO ELECTRONICS
RJ	REATION JET
TD	TIME DELAY
Y	YAW

FOLD-OUT #2

Figure 3-3. CM-SM Separation Mission Success Logic Diagram, Spacecraft 011

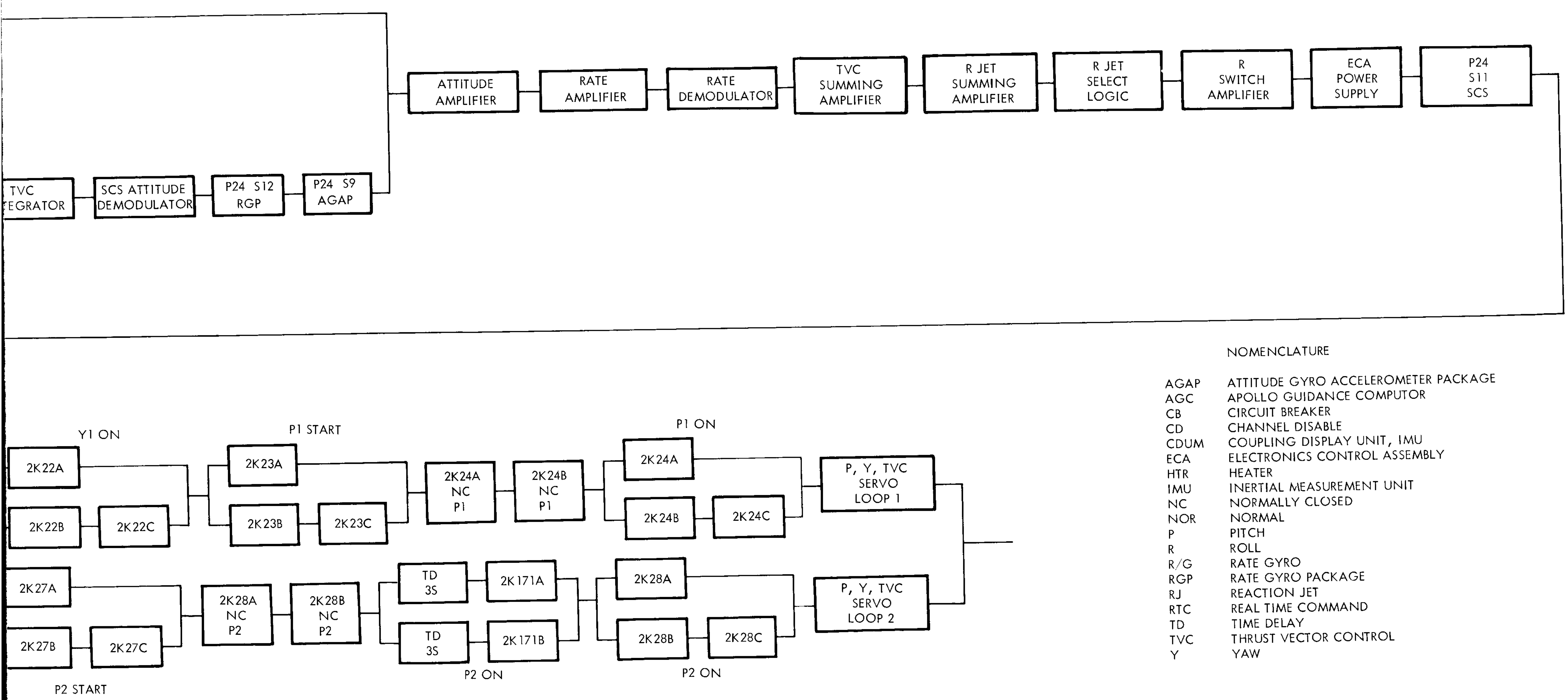

G&N ΔV MODE
2K36C
2K36A
2K36B
2K36A
2K36B
2K36C
I MU
AGC
CDUM
BACK UP RATE (FIGURE 3-7)
ARM SPS THRUST (FIGURE 3-11)
+X TRANSLATION
2K41A
2K41B
2K42A
2K42B
SPS ENGINE HOLD
2K45C NC
2K45A NC
2K45E NC
2K45C
SOLENOID DRIVER A
SOLENOID DRIVER B
THRUST LOGIC
AUXILIARY POWER SUPPLY
G&N ATTITUDE DEMODULATOR
IMU-HTR
P22 CB 60
P22 CB 21
AGC
P22 CB 56
P22 CB 57
SCS ΔV MODE
DIRECT ULLAGE
G&N FAIL (FIG 3-10)
LV-SC SEPARATION (FIGURE 3-5)
2K112A
2K112C
2K112A
2K112B
2K112C
2K112B
2K114A
2K114C
2K114A
2K114B
2K114C
2K114B
2K115A
2K115C
2K115A
2K115B
2K115C
2K115B
2K57A
2K57B
RTC 77 DIRECT ULLAGE
1K72A
1K72B
1K31A
1K31F
1K31B +Y
1K31G +Y
1K31E -Y
1K31K -Y
1K31C +P
1K31H +P
1K31D -P
P9 R B&D CD
P9 P CD
P9 Y CD
P9 R A&C CD
P7ΔV THRUST SWITCH NOR SET NO. 1
P7ΔV THRUST SWITCH NOR SET NO. 2
R RJ DRIVER A
RRJ DRIVER B
SCS AC
P25 CB45
P25 CB46
SYSTEM
P25 CB43
P25 CB44
YAW
P25 CB31
P25 CB32
PITCH
P25 CB39
P25 CB40
ROLL B&D
P25 CB33
P25 CB34
ROLL A&C
P25 CB35
P25 CB36
ARM SPS THRUST
1K47A
1K47B
1K47C
1K47D
1K47E
LV-SC SEPARATION (FIGURE 3-5)
TD 2S
2K172A
TD 2S
2K172B
GIMBAL POSITION SET (FIGURE 3-12)
2K102
2K108
2K103
2K104

FOLD-OUT #1



IMU
P22 CB 58
P22 CB 59
SPS ENGINE HOLD
DIRECT THRUST ON
DIRECT THRUST OFF
1K31J -P
2K121A
2K121C
2K121A
2K121B
2K121C
2K121B
2K45A
2K45D
2K45B
2K45E
DIRECT THRUST ON A
DIRECT THRUST ON B
1K12A
1K12B
1K12D
1K12C
RTC DIRECT THRUST ON
1K78A
1K78B
RTC 57
1K77A
1K77B
R R/G
P R/G
Y R/G
R/G ELECTRONICS
P BMAG
P BMAG ELECTRONICS
Y BMAG
Y BMAG ELECTRONICS
R BMAG
R BMAG ELECTRONICS
IN
T GIMBAL POSITION SET
2K39A PITCH
2K40A NC PITCH
RESISTOR 1 SET
2K39B YAW
2K40B NC YAW
RESISTOR 2 SET
ND GIMBAL POSITION SET
2K39A P
2K40A P
2K53A NC P
RESISTOR 3 SET
2K39B Y
2K40B Y
2K53B NC Y
RESISTOR 4 SET
2K109
2K105
2K106
2K107
2K39A P
2K40A P
2K53A P
RESISTOR 5 SET
2K39B Y
2K40B Y
2K53B Y
RESISTOR 6 SET
D GIMBAL POSITION SET
P1 ON
Y2 START
TD 2S
2K169A
TD 2S
2K169B
GIMBAL MOTOR ON (FIGURE 3-8)
Y1 START
TD 1S
2K167A
TD 1S
2K167B
Y2 START
2K21A
2K21B
2K21C
Y1 2K22A NC
Y1 2K22B NC
Y1 ON
P1 START
TD 1.5S
2K168A
TD 1.5S
2K168B
2K25A
2K25B
2K25C
Y2 2K26A NC
Y2 2K26B NC
TD 2.5S
2K170A
TD 2.5S
2K170B
Y2 ON
P2 START
2K26A
2K68B
2K26C
Y2 ON

FOLD-OUT #2



NOMENCLATURE

AGAP	ATTITUDE GYRO ACCELEROMETER PACKAGE
AGC	APOLLO GUIDANCE COMPUTOR
CB	CIRCUIT BREAKER
CD	CHANNEL DISABLE
CDUM	COUPLING DISPLAY UNIT, IMU
ECA	ELECTRONICS CONTROL ASSEMBLY
HTR	HEATER
IMU	INERTIAL MEASUREMENT UNIT
NC	NORMALLY CLOSED
NOR	NORMAL
P	PITCH
R	ROLL
R/G	RATE GYRO
RGP	RATE GYRO PACKAGE
RJ	REACTION JET
RTC	REAL TIME COMMAND
TD	TIME DELAY
TVC	THRUST VECTOR CONTROL
Y	YAW

FOLD-OUT #3

Figure 3-4. ΔV Maneuver Mission Success Logic Diagram, Spacecraft 011

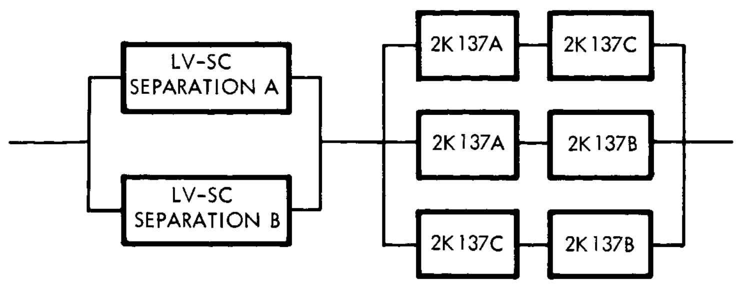
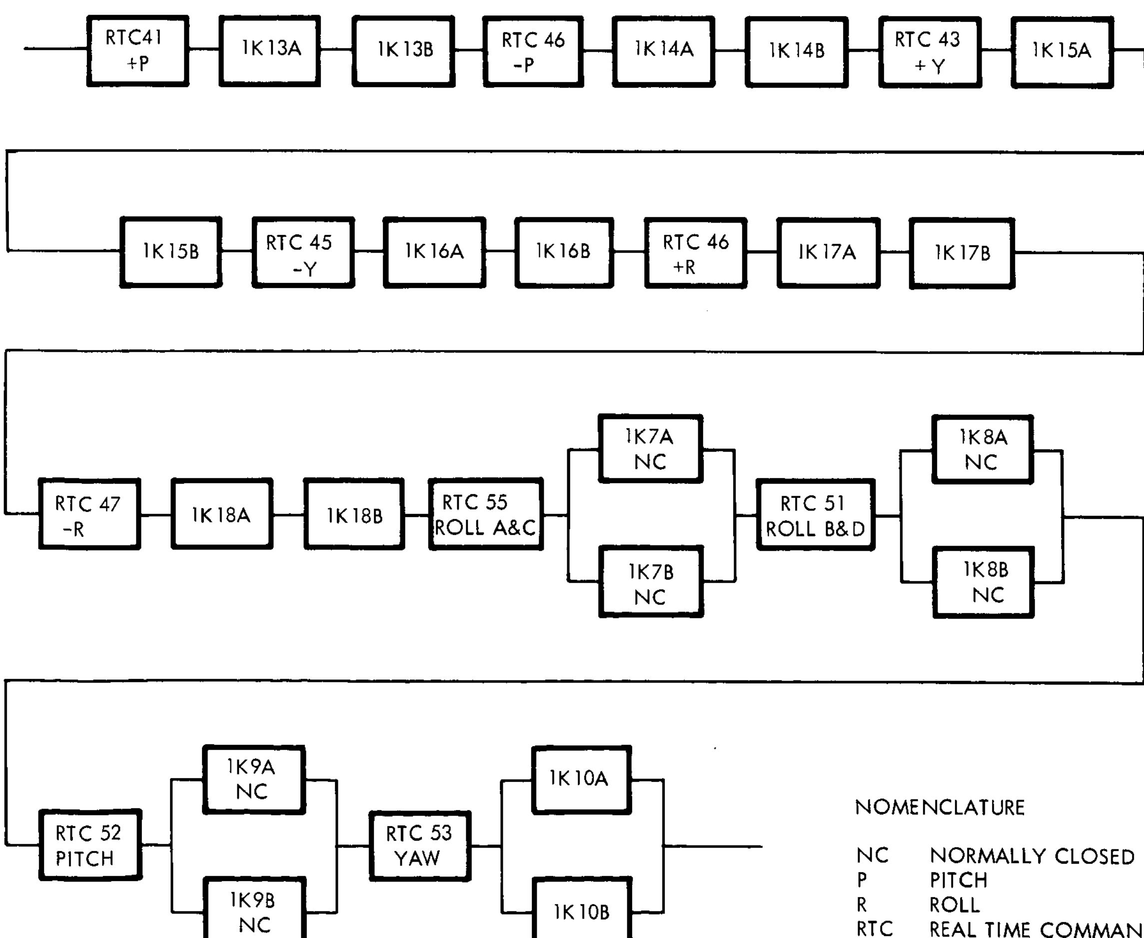


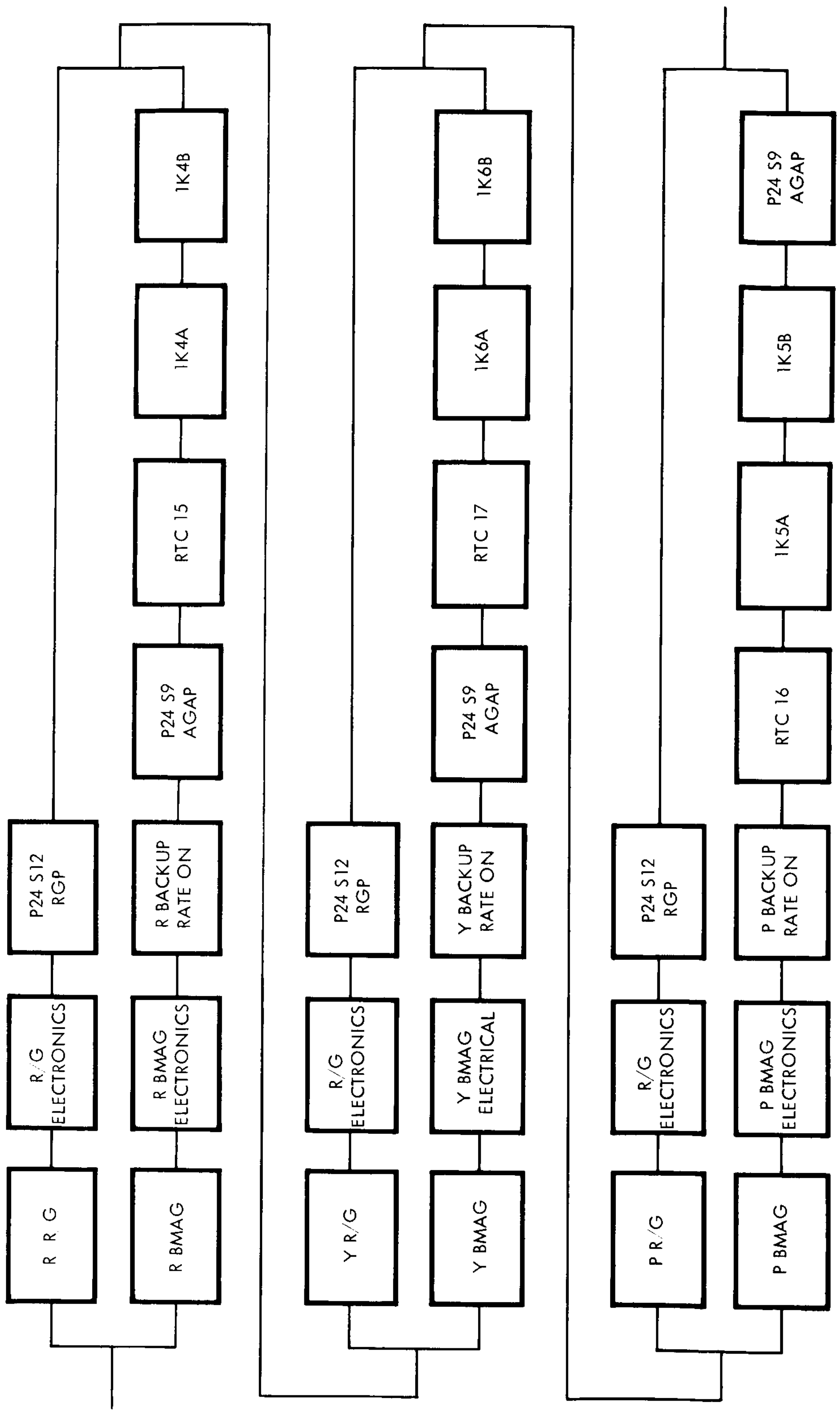
Figure 3-5. Launch Vehicle - Spacecraft Separation Logic Diagram



NOMENCLATURE

NC	NORMALLY CLOSED
P	PITCH
R	ROLL
RTC	REAL TIME COMMAND
Y	YAW

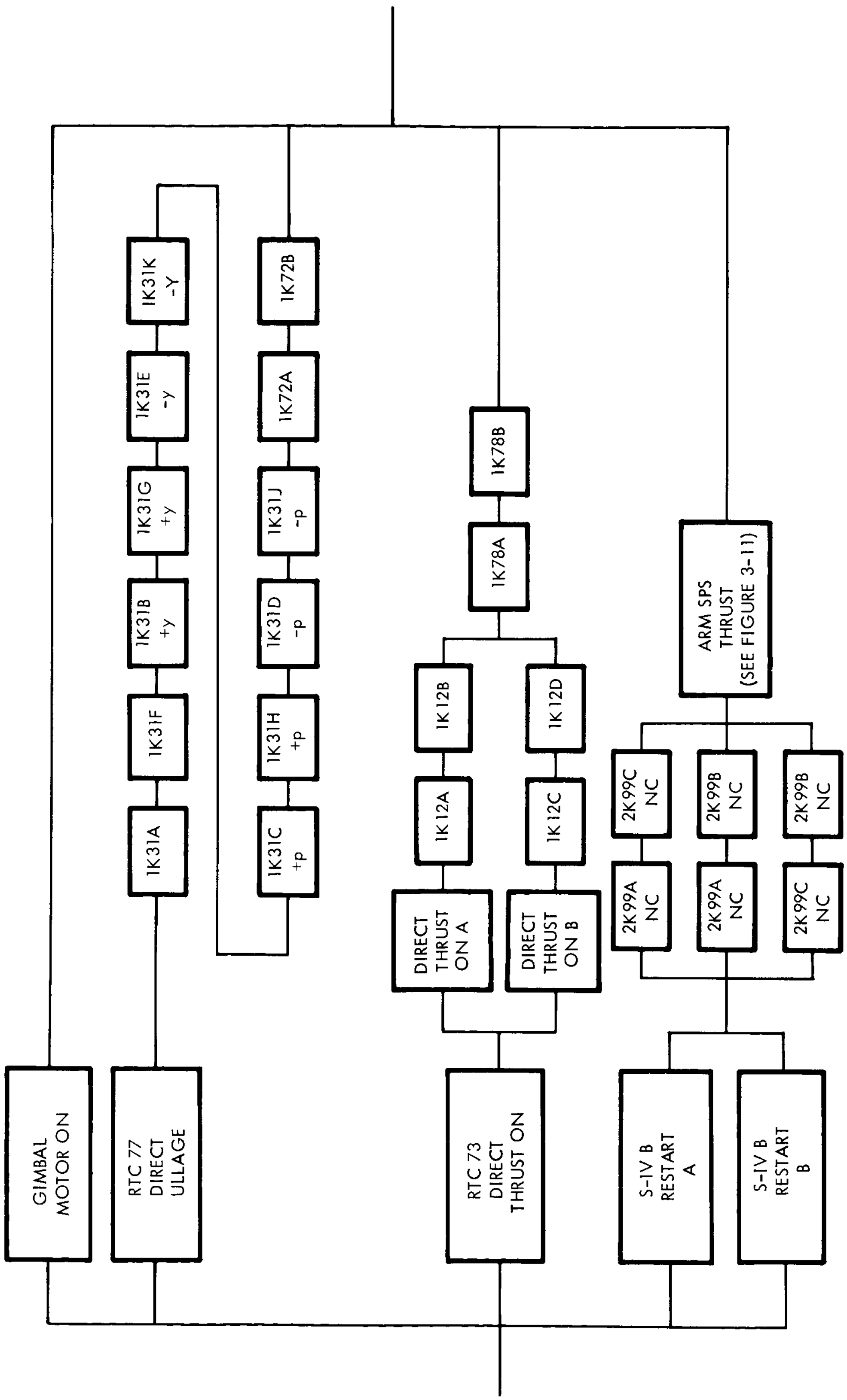
Figure 3-6. Direct Spacecraft Control Logic Diagram



NOMENCLATURE

AGAP	ATTITUDE GYRO ACCELEROMETER PACKAGE
BMAG	BODY-MOUNTED ATTITUDE GYRO
P	PITCH
R	ROLL
R/G	RATE GYRO
RGP	RATE GYRO PACKAGE
RTC	REAL TIME COMMANDS
Y	YAW

Figure 3-7. Backup Rate Logic Diagram



NOMENCLATURE

NC NORMALLY CLOSED
RTC REAL TIME COMMAND

Figure 3-8. Gimbal Motor On Logic Diagram

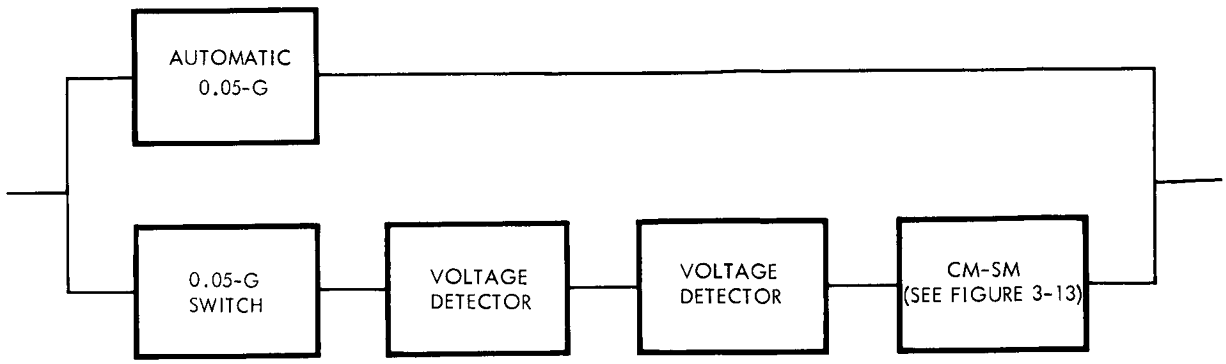


Figure 3-9. 0.05-G Logic Diagram

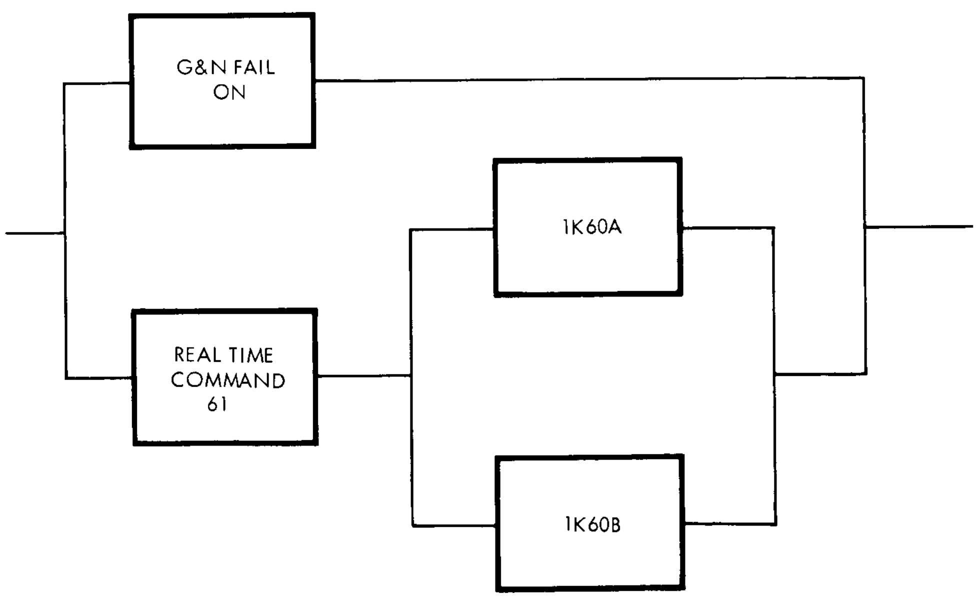
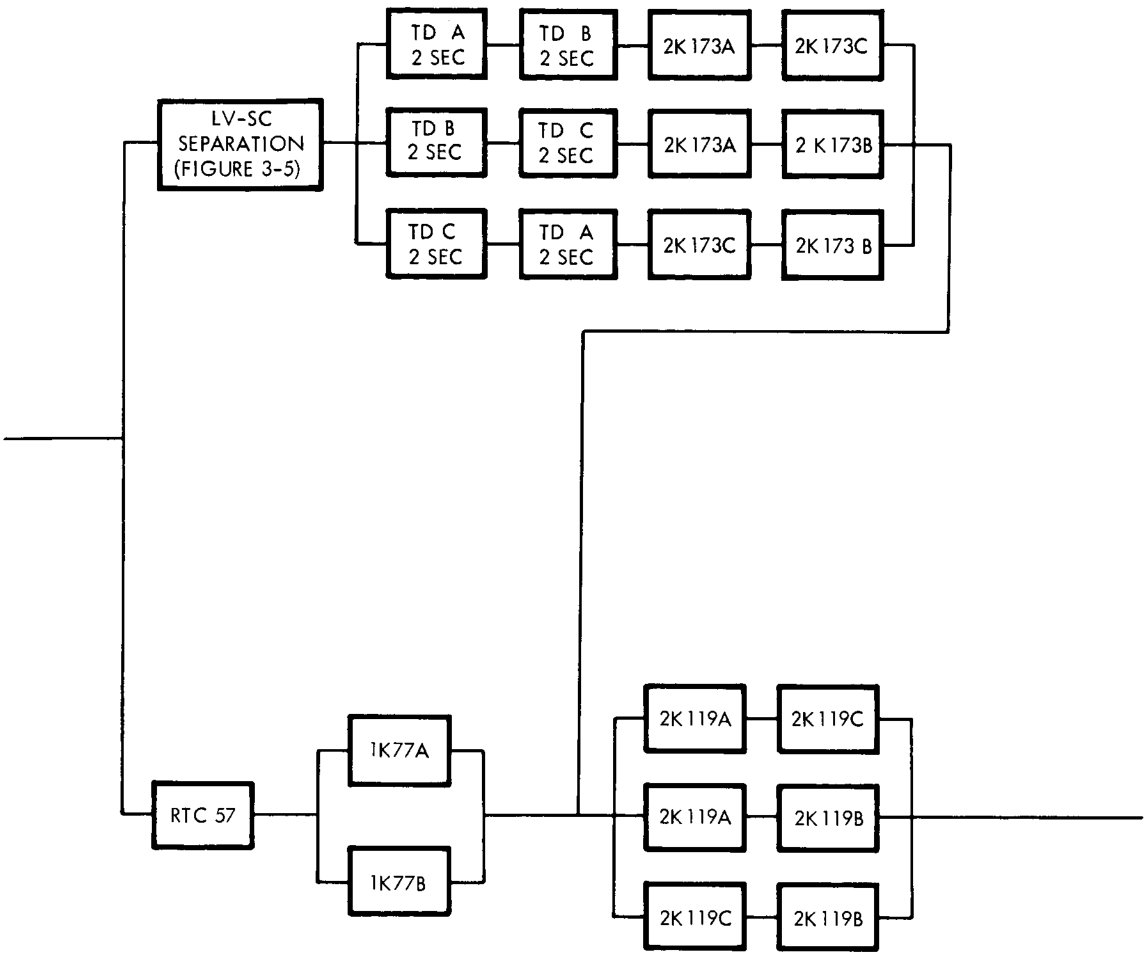


Figure 3-10. G&N Fail Logic Diagram



NOMENCLATURE

RTC REAL TIME COMMAND
TD TIME DELAY

Figure 3-11. Arm SPS Thrust Logic Diagram

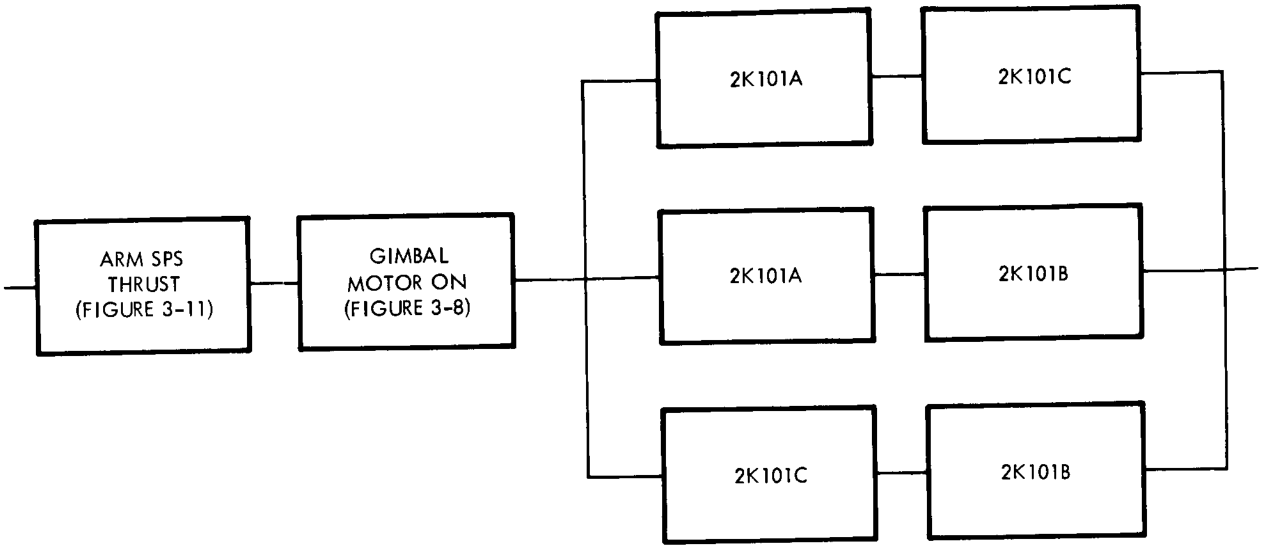


Figure 3-12. Gimbal Position Set Logic Diagram

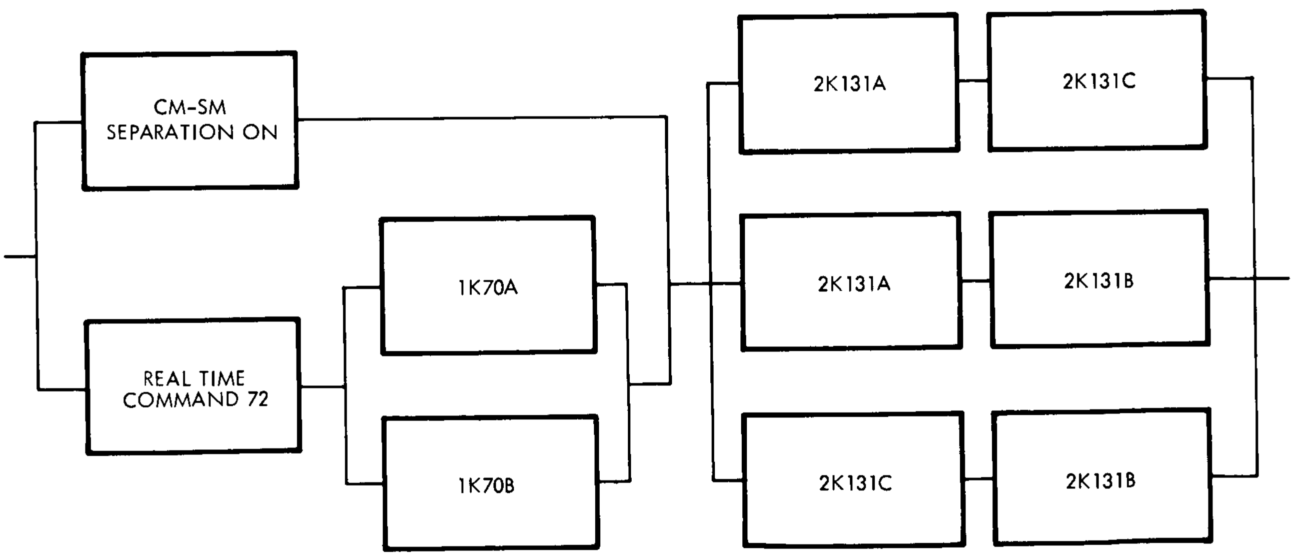


Figure 3-13. CM-SM Separation Logic Diagram

Table 3-2 shows a comparison between the operating time constraints on Apollo GN&C and SCS equipment necessary to meet the integrated electronics subsystems mission success probability of 0.9785 for Spacecraft 012 IMD required equipment operating times. Maximum duration values reflected in this table represent the 10.6-day mission. Table 3-2 also shows that the operating time constraints for Apollo GN&C and SCS equipment preclude the meeting of IMD Spacecraft 012 mission attitude control requirements without degrading mission success reliability.

3.6.2.5.1 Results

During the reliability requirements analyses, it was determined that without the COAS, the Apollo guidance computer (AGC), and the inertial measurement unit (IMU) the standby modes of operation exercise a limiting influence upon the probability of joint mission success of the equipment combinations used, while with the COAS the PCM telemetry modules exercise a limiting influence upon reliability gains. For this reason the results of the analyses contained in Tables 3-3 and 3-4 show gains to be expected from the COAS with and without the PCM telemetry included in the reliability logic configuration. This division was made to show the incremental gains in reliability exclusively afforded by the COAS to the GN&C and the SCS subsystems of the spacecraft integrated electronics subsystems. Accordingly, in the most favorable configuration, the mission success probability value of 0.997450 found in Row 1, Column 3, of Table 3-3 shows that the COAS is sufficient to assure that the GN&C and the SCS subsystems will meet the marginal probability requirements to achieve the 0.9785 spacecraft integrated electronics subsystems apportionment or objective value. On the other hand, the 0.970390 mission success probability value found in Row 1, Column 3, of Table 3-4 shows that, in addition to the COAS, redundancy will be required in the PCM telemetry to achieve the required objective value.

In addition to analyses involving equipment configurations, failure rates, and operating times, consideration was given to performance requirements that must be satisfied to meet mission objectives. Entry parameters assumed by S&ID for the tentative manual thrust vector control mission were as follows:

Allowable 3σ touchdown disperson	100 NM
Nominal orbital altitude	105 NM
Nominal impulse ΔV	750 fps
Nominal thrust pitch attitude (down and aft)	70 deg
3σ allowable thrust pointing uncertainty	±10 deg

The results of simulation studies in which the commander's window was used for the performance of guidance steering during manual thrust vector control maneuvers, have indicated guidance steering accuracies (less than a ±7 degrees allocation) are within the ±10 degree uncertainty allowances noted previously. In addition, this particular constraint can be widened by NASA's extension of entry dispersion parameters. Simulation studies employing COAS under development for Block II vehicles have demonstrated capabilities of a device of this type for meeting spacecraft pointing accuracy requirements. For more refined analyses of this backup mode of operation, quantitative indices of performance capabilities of respective operating paths will be required.

Table 3-2. Spacecraft 012 Equipment Operating Time Comparisons

Parameter	Time Constraints to Attain 0.9785 Reliability (hours)	IMD GN&C and SCS Operating Times (hours)	IMD GN&C and Worst-Case SCS Operating Times (hours)
Mission duration	130	248	248
IMU and electronics	5	26	26
IMU standby	243	222	222
Optics and electronics	4	20	20
AGC, displays and control keyboard	5	26	26
AGC standby	243	222	222
Body-mounted attitude gyros and electronics	10	74.83	248
Rate gyro package	10	10	10
Flight director attitude indicator	14	100.83	248
Gyro coupling unit	14	74.83	248
SCS control electronics	14	74.83	248

Table 3-3. Reliability Gains From Backup COAS Modes of Operation, Excluding PCM Telemetry

Equipment Configurations and Operating Time	Reliability: Operations Without COAS: Mission Success Probability	Reliability: Operations Without COAS: Mission Failures (Mission Losses per 1000 Missions)	Reliability: Operations Including COAS: Mission Success Probability	Reliability: Operations Including COAS: Mission Failures (Mission Losses per 1000 Missions)	Reliability Gains (Reduction in Mission Losses per 1000 Missions)
GN&C and SCS equipment operating times to meet IMD test objectives (26 hours, GN&C; 74. 83 hours, SCS)	0. 898530	101. 47	0. 997450	2. 55	98. 92
GN&C equipment operating times to meet IMD test objectives with maximum duration SCS operating time (26 hours, GN&C; 248 hours, SCS)	0. 830110	169. 89	0. 976570	23. 43	146. 46

Table 3-4. Reliability Gains From Backup COAS Modes of Operation, Including PCM Telemetry

Equipment Configurations and Operating Times	Reliability				Reliability Gains (Reduction in Mission Losses per 1000 Missions)
	Operations Without COAS		Operations Including COAS		
	Mission Success Probability	Mission Failures (Mission Losses per 1000 Missions)	Mission Success Probability	Mission Failures (Mission Losses per 1000 Missions)	
GN&C and SCS equipment operating times to meet IMD test objectives (26 hours, GN&C; 74.83 hours, SCS)	0.874150	125.85	0.970390	29.61	96.2
GN&C equipment operating times to meet IMD test objectives with maximum duration SCS operating time (26 hours, GN&C; 248 hours, SCS)	0.806050	193.95	0.948270	51.72	142.23

The addition of the COAS to Block I manned spacecraft eliminates, in effect, the single-point failure aspects of the scanning telescope assembly of the GN&C subsystem which is required onboard for both GN&C and SCS attitude-reference alignment. With the employment of this device, a significant reliability growth toward the S&ID allocated mission success apportionment value of 0.97850 for the integrated spacecraft electronics subsystems can be realized. This growth is indicated by the results shown in Row 1 of Table 3-3 in which employment of the COAS affords a reduction in mission losses per 1000 missions from 101.47 to 2.55. Accordingly, a recommendation was made that the COAS be provided for the performance of backup GN&C and SCS functions for Spacecraft 012 and 014 (A205).

3.6.3 TEST PROGRAM

3.6.3.1 AGE-6 Tests

Hardware-oriented, open-loop testing of Apollo guidance electronics (AGE) is in progress in the NAA/S&ID Guidance and Control Laboratory. This testing will provide the first verification of the electrical interfaces between the G&N and spacecraft subsystems. Preliminary tests, in keeping with basic interface control documents, were completed. Five failures in AGE equipment were reported by NCR's to NASA with information transmitted to MIT/IL. Information is being coordinated to assure that any specific corrective action is communicated to S&ID.

3.6.3.2 G&N Subsystem Development Plan

Reliability inputs were submitted to SID 64-2055, Guidance and Navigation Subsystem Development Plan. Areas of principal interest included provisions for performance verification and data acquisition for reliability assessment purposes.

3.6.3.3 Apollo Reliability Modeling

A review of the preliminary Apollo Reliability Modeling Plan was completed. Comments concerning this document are in progress to assure that the close correlation factors needed between G&N control hardware and the machine programming techniques are utilized in this model. The development of a model to establish optimum statistical and test data requirements, which must be satisfied to support the Reliability assessment model, is being considered.

3.6.3.4 MIT/IL Qualification Status List

A review was conducted of the MIT/IL Qualification Status List ND1002034, which was converted to IBM cards. Initial printouts revealed that a considerable amount of acquired data is in coded form. A computer program is being prepared to facilitate the evaluation of data acquired from the qualification status list, in support of the Reliability assessment model.

3.6.4 PROBLEM AREAS

Three significant reliability failures of the AGE-6 guidance and navigation equipment occurred in the Apollo guidance computer, the optics hand controller, and in a ternary current switch.

While attempting to insert commands into the Apollo guidance computer by use of the manual control switches (computer in computer-control mode), the computer became locked-out and would not accept commands from any source. The manual controls, attitude-hold, and attitude-follow are not effective in the computer-control mode and normally would not be actuated in this configuration. However, if inadvertent actuation during a mission were to cause lockout, a serious condition might result, because relief of this condition in the AGE-6 computer required 3 hours of introduction of random transients by throwing the power switch on and off.

The optics hand controller is a small joystick which rotates microswitches against actuating buttons. Leads to the microswitches were flexed by each movement of the joystick and a lead eventually broke.

The ternary current switch is a solid-state pulse generator that receives position signals, converts them, and applies them to a position-control servo-loop. The output of the ternary control switch was incorrect in magnitude and frequency. The scale factor of position commands converted by this switch was only about one-half of the required value.

These problems have been reported to NASA for resolution with the appropriate contractor.

3.6.5 PLANNED ACTIVITIES

During the next reporting period, preliminary reliability logic diagrams, single-point failure summaries, and failure mode and effects analyses will be completed for Spacecraft 014, 017, and 020. These tasks in updated and final form will be completed on Spacecraft 006, 012, and 009, respectively. Table 3-5 is a schedule of these planned activities.

Table 3-5. GN&C Analysis Activity for the 15th Quarter

Tasks	Block I Spacecraft					
	006	009	012	014	017	020
Logic diagrams	5 August Update	9 July Final	20 August Update	6 July Preliminary	20 July Preliminary	25 August Preliminary
Single-point failure summary	25 August Update	10 August Final	20 August Update	15 July Preliminary	9 August Preliminary	8 September Preliminary
Failure mode and effects analysis	5 August Prelim-inary		16 August Update	15 July Preliminary	5 August Preliminary	10 September Preliminary

3.7 INSTRUMENTATION

3.7.1 SUMMARY

The major portion of the instrumentation test effort during this reporting period involved the completion of qualification testing for six instrumentation systems. A failure in the weldable surface thermocouple during qualification testing was resolved, qualification retesting was initiated, and retesting was successfully completed during this report period.

Analysis and end-item support was given in the areas of logic diagrams, single-point failure summaries, minimum airworthiness requirements, and FMEA's.

3.7.2 ANALYSIS

Analysis of Boilerplate 23A, Spacecraft 002, 010, 009, 011, and 012 resulted in the following documents:

Logic diagrams (preliminary)	Spacecraft 010, 011, and 012; Boilerplate 23A
Logic diagrams (updated)	Spacecraft 002
Single-point failure summary (preliminary)	Spacecraft 010 and 012 (in process)
Single-point failure summary (updated)	Spacecraft 002, 009, and 011
Minimum airworthiness requirement and status	Spacecraft 002 and 010
Failure mode effect analysis	Spacecraft 011 and 012 (in process)

3.7.3 PROBLEM AREAS

3.7.3.1 Test Laboratory Surveys and Qualification Test Monitoring

As reported last quarter, a review of test reports showed that test laboratory surveys and qualification test monitoring should be emphasized. Test laboratory discrepancies are reported too late to recover time and money expended. Most of these test laboratories were either not surveyed or were surveyed over a year ago. Many of these discrepancies could be eliminated if pretest surveys were conducted or tests monitored.

3.7.3.2 Surface Thermocouple Failure (ME361-0012)

During the temperature-vacuum test of the surface thermocouple (manufactured by HyCal Engineering), the thermocouple probe broke loose from the flange to which it was welded. The failure occurred because of a poor spotweld. This defect could have been detected if a weld check had been part of the acceptance test. In the future, the supplier will perform a pull test on every tenth weld on a dummy unit as part of the acceptance test procedure. Four more sensors were furnished for qualification testing, which was successfully completed.

3.7.4 SUBCONTRACTOR MANAGEMENT

The Reliability audit of the Philco Corporation in Palo Alto scheduled for this reporting period was rescheduled.

3.7.5 PLANNED ACTIVITIES

Significant tests planned for the next quarter will include off-limit tests on instrumentation as installed in the heat shield and in the pressure vessels of the propulsion systems.

Preliminary planning was initiated on tests of installation integrity of heatshield instrumentation at the hypervelocity test facility, Research Center of Rocketdyne Division, Santa Susanna. Test results will be reported in the next quarter.

Combined test procedures (vibration, temperature, and over-pressure) were written for off-limits tests of propellant system pressure transducers that will be installed in critical subsystems. Mechanical failure of these transducers will cause failure of the subsystem. The off-limits tests will be conducted next quarter by NAA on transducers that have completed qualification tests.

3.8 STABILIZATION AND CONTROL

3.8.1 SUMMARY

Effort was expended on integrated circuit review, parameter variation and stress testing review, runaway jet detector study, review of CQ-1 test reports, and preparation for CQ-2 and SQ-1 qualification testing.

3.8.2 ANALYSIS

3.8.2.1 Spacecraft 009 Development Engineering Inevestigation (DEI)

Two DEI's were held at Downey with representatives from NASA and NAA/S&ID. The two items affecting reliability discussed during the initial DEI were as follows: (1) The present SCS configuration would not have the required capability of direct ullage because the spacecraft does not have attitude control, thus causing the SCS gyros to go to their stops—corrective action would be a wiring change to use attitude control during a direct ullage maneuver, preventing the gyros from going to their stops; and (2) there will not be complete ground coverage of the flight because the coverage ships are being deployed elsewhere in support of the Gemini flights. The ground control backup capability is based upon total ground coverage of the vehicle during flight. (This item was left open with NASA action required.)

The second DEI was divided into groups with NASA-Reliability reviews of Spacecraft 009 workbooks. No action was generated from this review.

3.8.2.2 Runaway Jet Detection

Apollo Reliability has supported Engineering in determining the need for a runaway jet detector. NAA/S&ID presented a detection unit design which NASA rejected because it detected only those failures in the SCS that would cause a runaway jet. Work is proceeding to determine what failures could cause a runaway jet, the failure frequencies associated with these failures, and means of detection. The most probable failure mode that could cause this condition is a valve stuck in the open position. The detection of this mode seems to be a problem, especially during the high-q portion of entry. Investigations are continuing.

3.8.2.3 Spacecraft 011 and 012 Failure Mode and Effects Analysis (FMEA)

Inputs pertaining to the SCS equipment were supplied for the guidance and control FMEA on Spacecraft 011 and 012.

3.8.3 SUBCONTRACTOR MANAGEMENT

3.8.3.1 Block II Parameter Variation and Stress Testing (PVST)

Two PVST reports on the Block II d-c amplifier and demodulator circuits were reviewed and accepted. No parts were found to be overstressed, and circuit operation with varied part-tolerance limits did not affect circuit operations.

3.8.3.2 Failure Mode and Effects Analysis

A Block II piece-part FMEA, based on the Engineering model configuration, was completed by Honeywell Reliability and is being reviewed by Honeywell Engineering.

3.8.3.3 Use of Integrated Circuits in Block II Hardware

Honeywell submitted information to support the use of integrated circuits in the Block II SCS. The data were reviewed, but further data are required to allow a reliability evaluation. The use of integrated circuits is being evaluated by NASA. S&ID was directed to present justification for their use. One of the prime reasons for not using integrated components is the inability of the suppliers to produce a high-reliability part within the stringent schedule constraints of the Apollo program. S&ID and Honeywell are reviewing all aspects, and it is expected that a decision will be reached soon on whether to utilize discrete parts in lieu of integrated circuits.

3.8.3.4 Logic Diagrams

Block II reliability logic diagrams were submitted to S&ID on the following SCS control functions:

Spacecraft maneuver
TVC (ullage and attitude hold)
TVC (engine on-off and thrust vector control)
Aerodynamics entry (after 0.059 g)

3.8.3.5 Block II SCS Procurement Specification

The Block II SCS Procurement Specification, Revision A, is being reviewed.

3.8.3.6 High-Reliability Handling Specification

Honeywell Reliability revised their specification on the handling of high reliability electronic, electrical, or electromechanical components. The revision now contains direction on the use of proper tools, proper soldering techniques etc., as well as direct handling provisions.

3.8.3.7 Block K Subsystem Procurement

Apollo Reliability is reviewing a Honeywell request for permission to selloff the first K subsystem containing parts that have not completed group B & C testing by the vendor. Presently, this request is not necessary because of rescheduled delivery dates. If it becomes necessary to allow the selloff with unqualified parts, NASA Reliability will be notified before permission is granted.

S&ID is notified daily of the B&C testing status. The date for completion of these tests is 22 June 1965, which is within the present delivery schedule.

3.8.4 TEST PROGRAM

3.8.4.1 CQ-1 and CQ-1 Updated Testing

Test reports on CQ-1 testing are being reviewed. The display/AGAP electronic control assembly is the last item to be reviewed. CQ-1 updated testing was initiated with no problems to date. The updated CQ-1 equipment will reflect those significant portions of the Block J equipment that differ from the original CQ-1 hardware. Also included in the updated CQ-1 will be fixes required by the original CQ-1 tests. All failure reports generated as a result of CQ-1 testing were closed out with acceptable corrective action being taken by Honeywell.

3.8.4.2 CQ-2 and SQ-1 Qualification Testing

Qualification test procedures are being generated by Honeywell for CQ-2 and SQ-1 testing. The present start dates for CQ-2 and SQ-1 testing are 15 July and 1 September, respectively, although NAA/S&ID is considering the possibility of moving the SQ-1 start date from September 1965 to July 1965.

3.8.4.3 NAA/S&ID Apollo Reliability Support to Qualification Program

Manpower schedules for support of CQ-2 and SQ-1 qualification testing are being established. The Reliability resident representative will represent S&ID Apollo Reliability during the qualification test program.

Additional monitoring will be provided as required. A review of all data to evaluate the start status of the SCS for CQ-2 and SQ-1 qualification testing was initiated in compliance with the qualification start procedure.

3.8.5 PLANNED ACTIVITIES

During the next quarter emphasis will include: (1) qualification of the Block I SCS in support of the Spacecraft 012 DD250 date of April 1966, (2) buy-off of K-Block subsystems, and (3) finalized failure mode and effects analysis for Block II in support of the Block II design freeze date.

4.0 GROUND SUPPORT EQUIPMENT

4.1 END-ITEM SUPPORT

As previously reported, the GSE Reliability effort was realigned to strengthen support of end-items. Additional reorganization on a subsystem basis was effected during this report period to reflect reorganization of ground support subsystem (GSS) Design Engineering, and project engineers of GSS Reliability were assigned to support discrete end-item and launch complexes. All data related to specific end-items that may have significant bearing on crew safety, mission success, and operational readiness are acquired by the project engineers for directing and controlling resolutions of problems. GSS milestones established for end-item vehicles are shown in Figure 1-2.

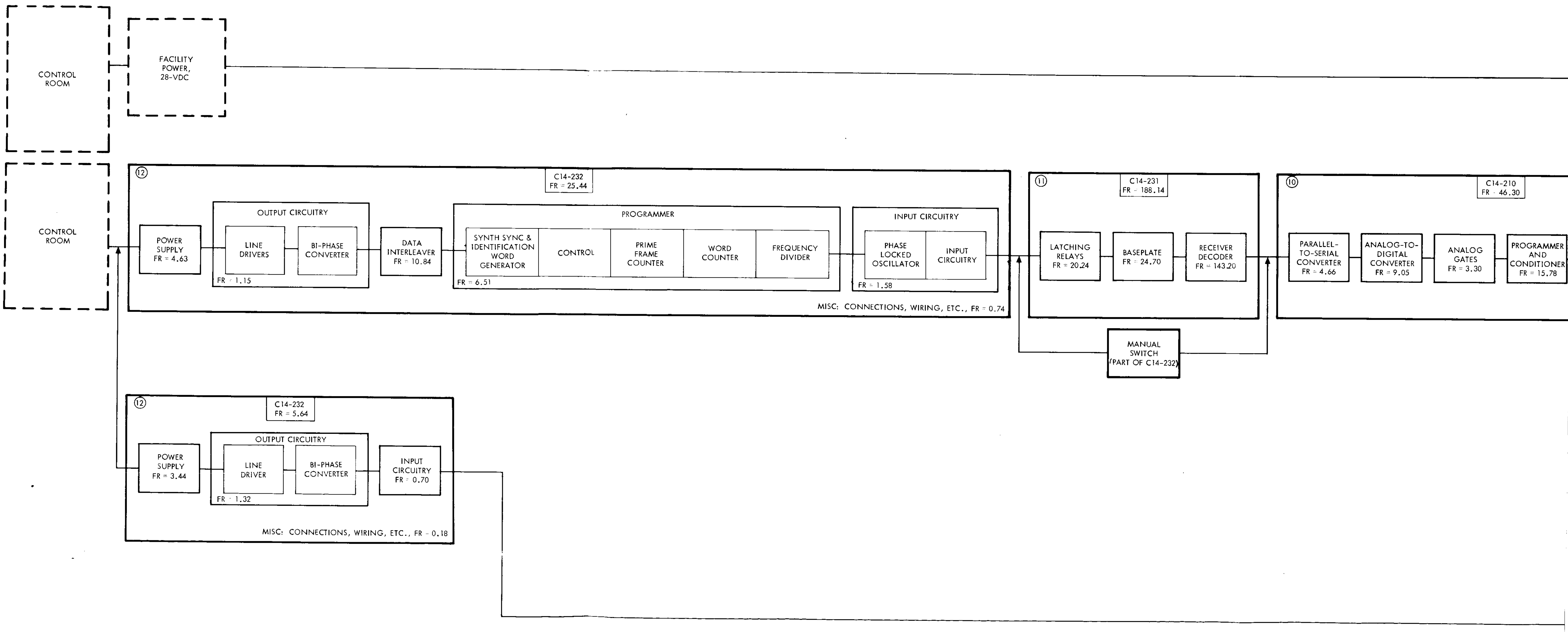
4.1.1 FUNCTIONAL LOGIC DIAGRAMS

Functional logic block diagrams (Figures 4-1 through 4-7) for the following seven subsystems reflecting Spacecraft 009 requirements at Launch Complex 34 were updated to include revised failure rate predictions.

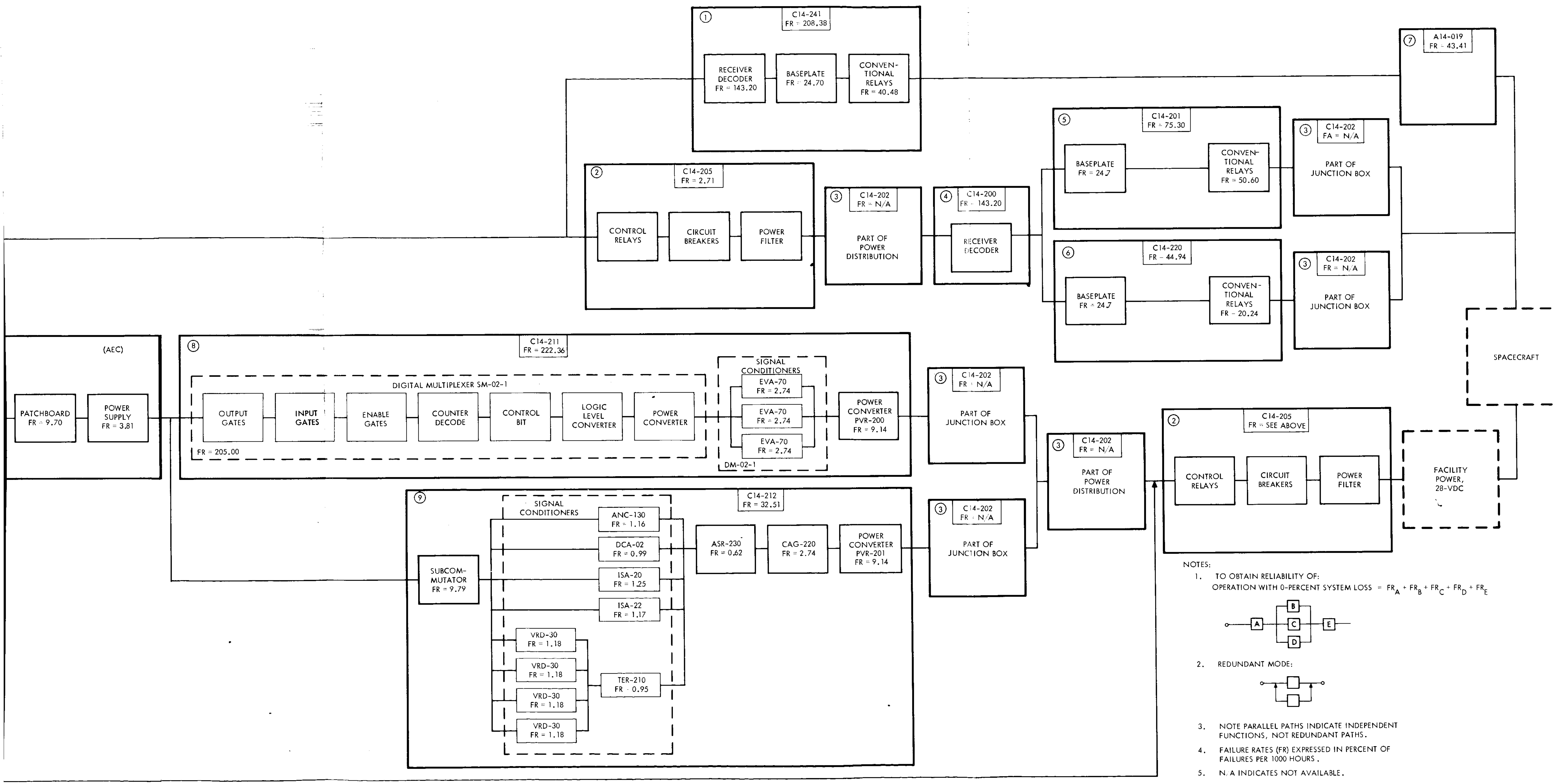
Subsystems	Figure No.
Communications and instrumentation (C&I)	4-1
Environmental control (ECS)	4-2
Earth landing (ELS)	4-3
Electrical power (EPS)	4-4
Launch escape (LES)	4-5
Reaction control (RCS)	4-6
Stabilization and control (SCS)	4-7

4.1.2 SPACECRAFT 009 FMEA's

Logic diagram and FMEA's were completed for Spacecraft 009. Inputs from these analyses were submitted for the Development Engineering Inspection (DEI) Phase I and II Review.


CONTROL ROOM
FACILITY POWER, 28-VDC
CONTROL ROOM
12
C14-232
FR = 25.44
POWER SUPPLY FR = 4.63
OUTPUT CIRCUITRY
LINE DRIVERS
BI-PHASE CONVERTER
FR = 1.15
DATA INTERLEAVER FR = 10.84
PROGRAMMER
SYNTH SYNC & IDENTIFICATION WORD GENERATOR
CONTROL
PRIME FRAME COUNTER
WORD COUNTER
FREQUENCY DIVIDER
FR = 6.51
INPUT CIRCUITRY
PHASE LOCKED OSCILLATOR
INPUT CIRCUITRY
FR = 1.58
MISC: CONNECTIONS, WIRING, ETC., FR = 0.74
11
C14-231
FR = 188.14
LATCHING RELAYS FR = 20.24
BASEPLATE FR = 24.70
RECEIVER DECODER FR = 143.20
MANUAL SWITCH (PART OF C14-232)
10
C14-210
FR = 46.30
PARALLEL-TO-SERIAL CONVERTER FR = 4.66
ANALOG-TO-DIGITAL CONVERTER FR = 9.05
ANALOG GATES FR = 3.30
PROGRAMMER AND CONDITIONER FR = 15.78
12
C14-232
FR = 5.64
POWER SUPPLY FR = 3.44
OUTPUT CIRCUITRY
LINE DRIVER
BI-PHASE CONVERTER
FR = 1.32
INPUT CIRCUITRY FR = 0.70
MISC: CONNECTIONS, WIRING, ETC., FR = 0.18

FOLD-OUT #1



FOLD-OUT #2

Figure 4-1. C&I Spacecraft 009 GSE Functional Logic Block Diagram

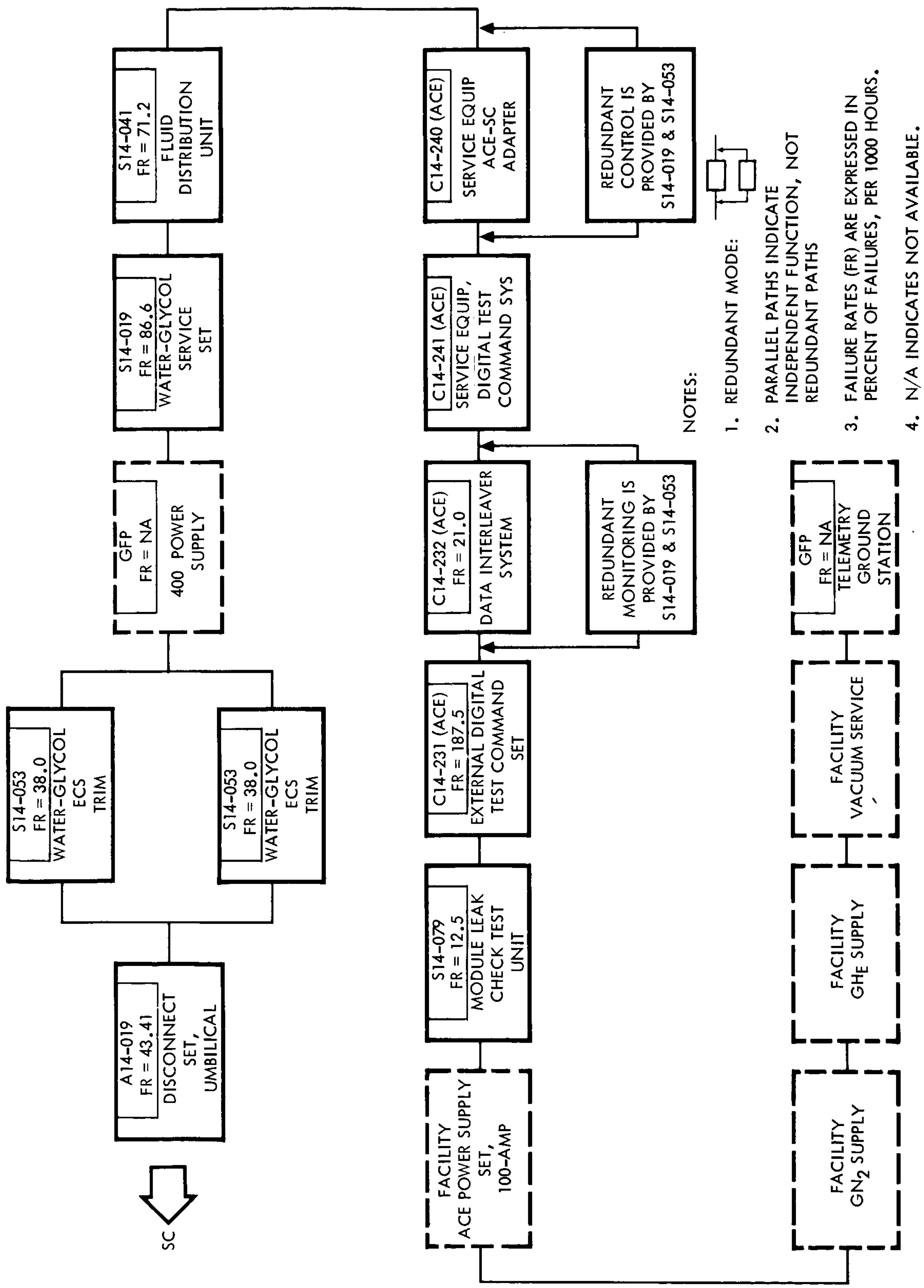
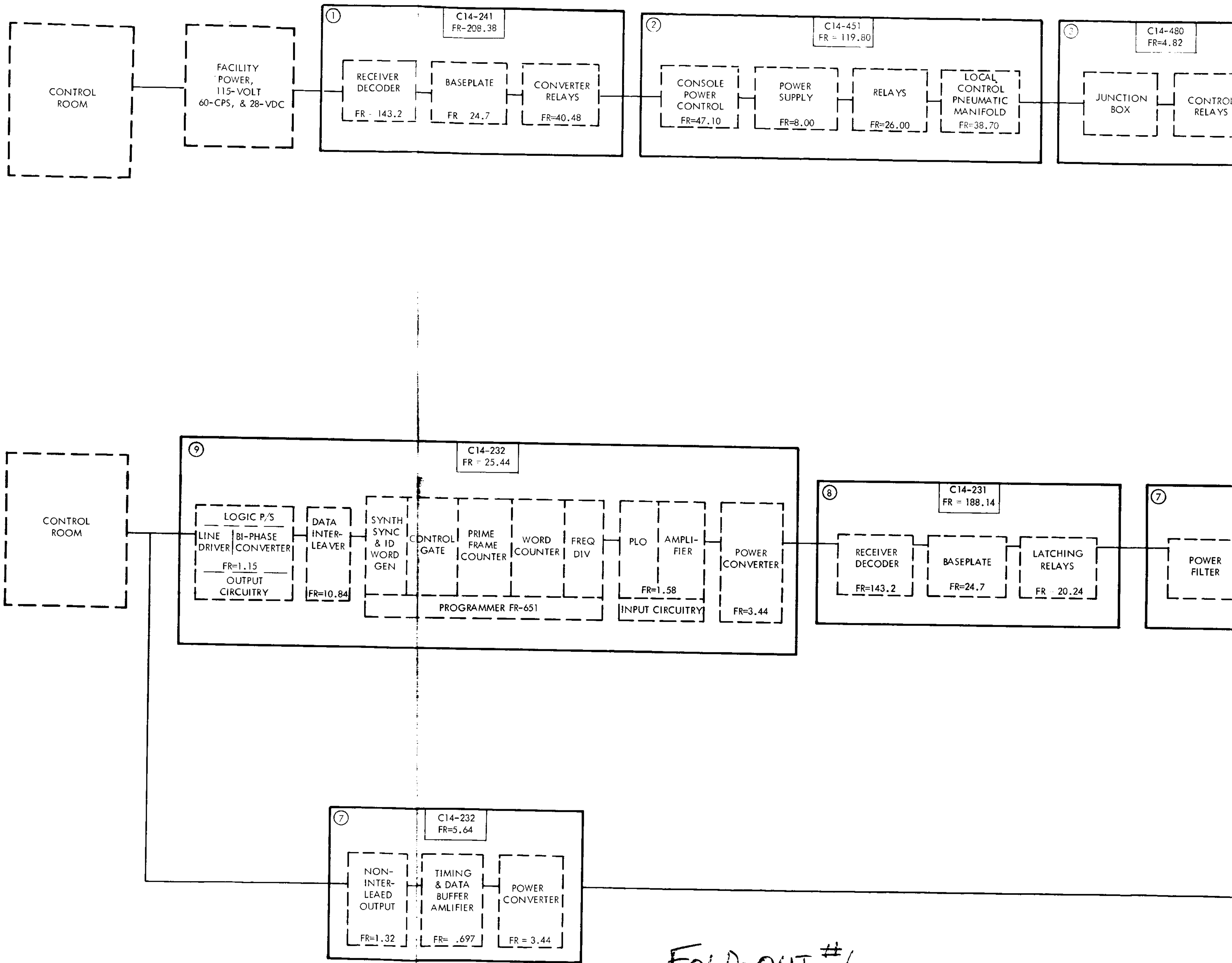
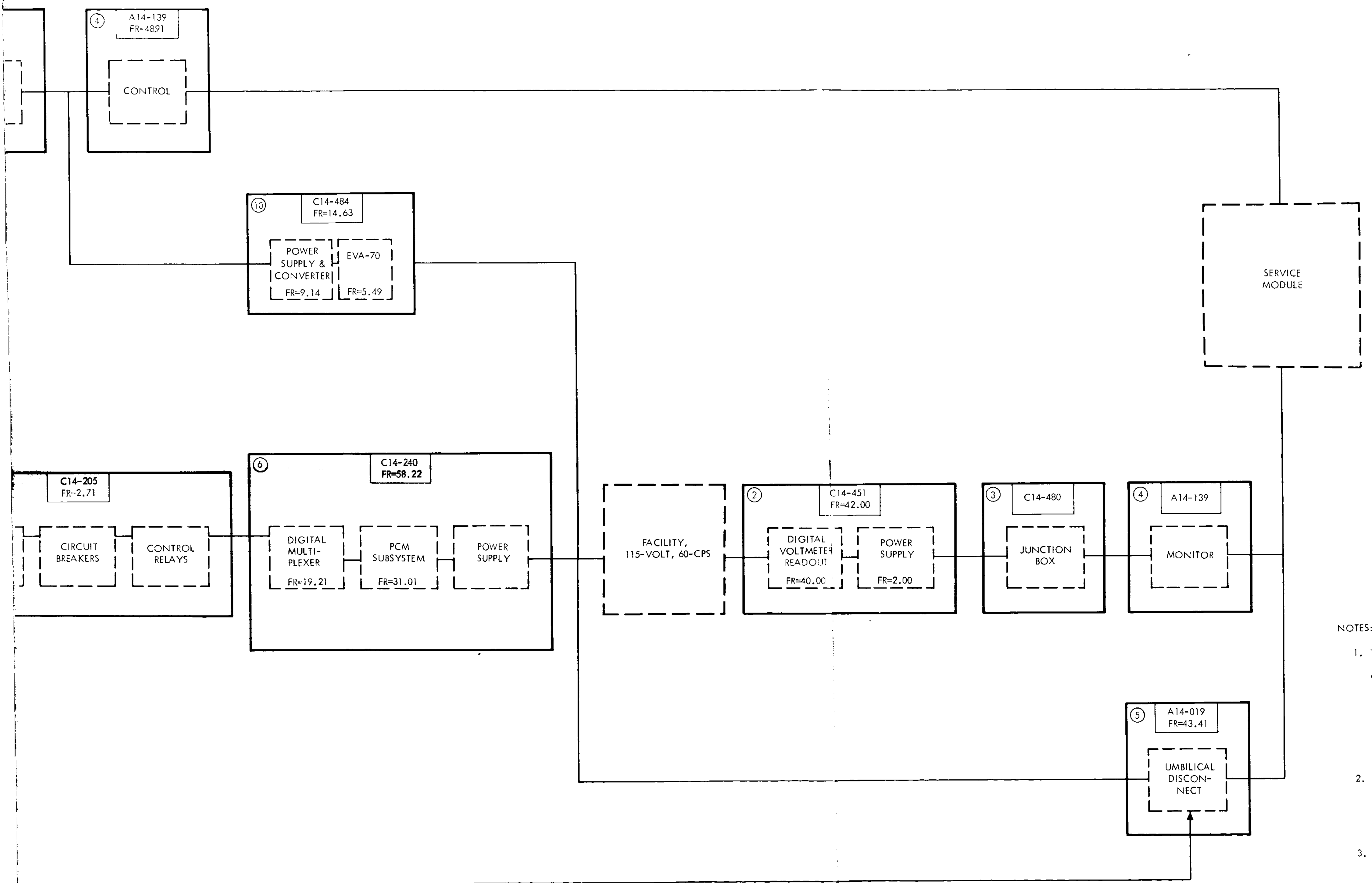


Figure 4-2. ECS Spacecraft 009 GSE Logic Block Diagram


CONTROL ROOM
FACILITY POWER, 115-VOLT 60-CPS, & 28-VDC
1
C14-241
FR-208.38
RECEIVER DECODER
FR - 143.2
BASEPLATE
FR 24.7
CONVERTER RELAYS
FR=40.48
2
C14-451
FR = 119.80
CONSOLE POWER CONTROL
FR=47.10
POWER SUPPLY
FR=8.00
RELAYS
FR=26.00
LOCAL CONTROL PNEUMATIC MANIFOLD
FR=38.70
3
C14-480
FR=4.82
JUNCTION BOX
CONTROL RELAYS
CONTROL ROOM
9
C14-232
FR = 25.44
LOGIC P/S
LINE DRIVER
BI-PHASE CONVERTER
FR=1.15
OUTPUT CIRCUITRY
DATA INTER-LEAVER
FR=10.84
SYNTH SYNC & ID WORD GEN
CONTROL GATE
PRIME FRAME COUNTER
WORD COUNTER
FREQ DIV
PROGRAMMER FR-651
PLO
AMPLI-FIER
FR=1.58
INPUT CIRCUITRY
POWER CONVERTER
FR=3.44
8
C14-231
FR = 188.14
RECEIVER DECODER
FR=143.2
BASEPLATE
FR=24.7
LATCHING RELAYS
FR 20.24
7
POWER FILTER
7
C14-232
FR=5.64
NON-INTER-LEAED OUTPUT
FR=1.32
TIMING & DATA BUFFER AMLIFIER
FR= .697
POWER CONVERTER
FR = 3.44

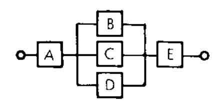
FOLD-OUT #1



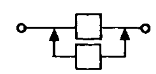
NOTES:

1. TO OBTAIN RELIABILITY OF:

   OPERATION WITH 0 PERCENT SYSTEM LOSS = $FR_A + FR_B + FR_C + FR_D + FR_E$



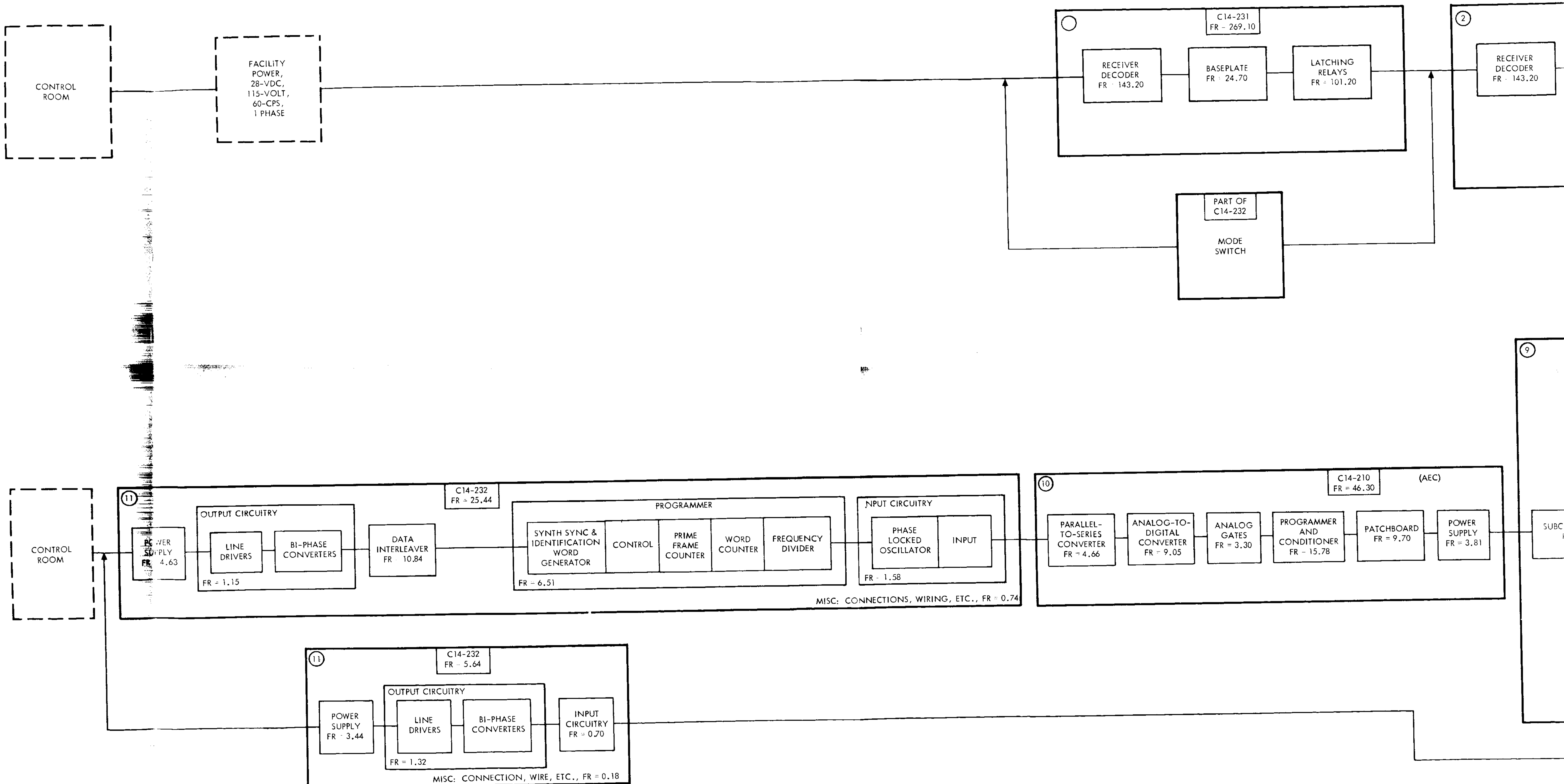
2. REDUNDANT MODE:



3. NOTE 1 PARALLEL PATHS INDICATE INDEPENDENT FUNCTIONS, NOT REDUNDANT PATHS.
4. FAILURE RATES (FR) EXPRESSED IN PERCENT OF FAILURES PER 1000 HOURS
5. N/A INDICATES NOT AVAILABLE

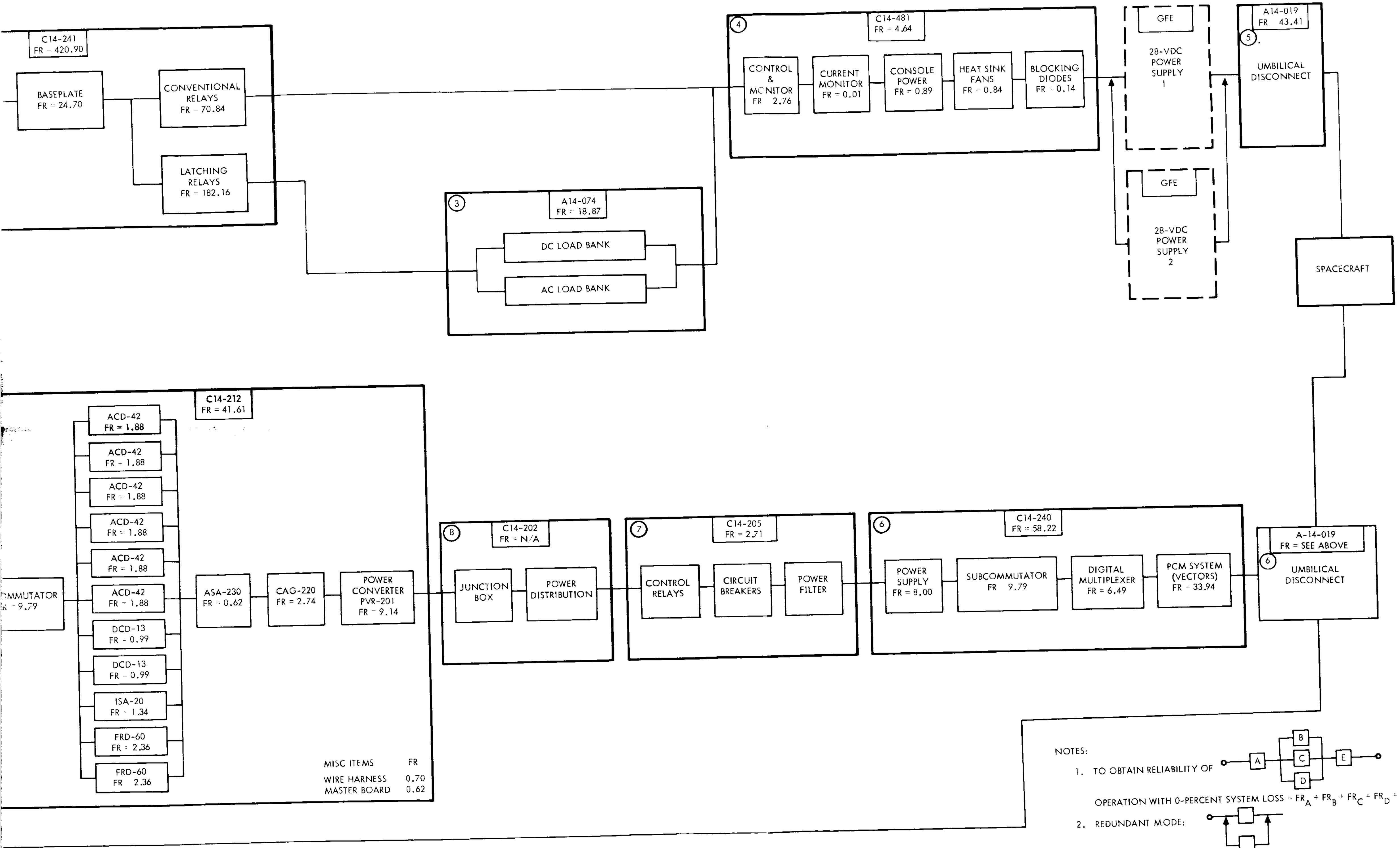
FOLD-OUT #2

Figure 4-3. ELS Spacecraft 009 GSE Functional Logic Block Diagram



CONTROL ROOM
FACILITY POWER, 28-VDC, 115-VOLT, 60-CPS, 1 PHASE
C14-231 FR = 269.10
RECEIVER DECODER FR = 143.20
BASEPLATE FR = 24.70
LATCHING RELAYS FR = 101.20
2
RECEIVER DECODER FR = 143.20
PART OF C14-232
MODE SWITCH
9
CONTROL ROOM
11
C14-232 FR = 25.44
POWER SUPPLY FR = 4.63
OUTPUT CIRCUITRY
LINE DRIVERS
BI-PHASE CONVERTERS
FR = 1.15
DATA INTERLEAVER FR = 10.84
PROGRAMMER
SYNTH SYNC & IDENTIFICATION WORD GENERATOR
CONTROL
PRIME FRAME COUNTER
WORD COUNTER
FREQUENCY DIVIDER
FR = 6.51
INPUT CIRCUITRY
PHASE LOCKED OSCILLATOR
INPUT
FR = 1.58
MISC: CONNECTIONS, WIRING, ETC., FR = 0.74
10
C14-210 FR = 46.30
(AEC)
PARALLEL-TO-SERIES CONVERTER FR = 4.66
ANALOG-TO-DIGITAL CONVERTER FR = 9.05
ANALOG GATES FR = 3.30
PROGRAMMER AND CONDITIONER FR = 15.78
PATCHBOARD FR = 9.70
POWER SUPPLY FR = 3.81
SUBC
11
C14-232 FR = 5.64
POWER SUPPLY FR = 3.44
OUTPUT CIRCUITRY
LINE DRIVERS
BI-PHASE CONVERTERS
FR = 1.32
INPUT CIRCUITRY FR = 0.70
MISC: CONNECTION, WIRE, ETC., FR = 0.18

FOLD-OUT #1

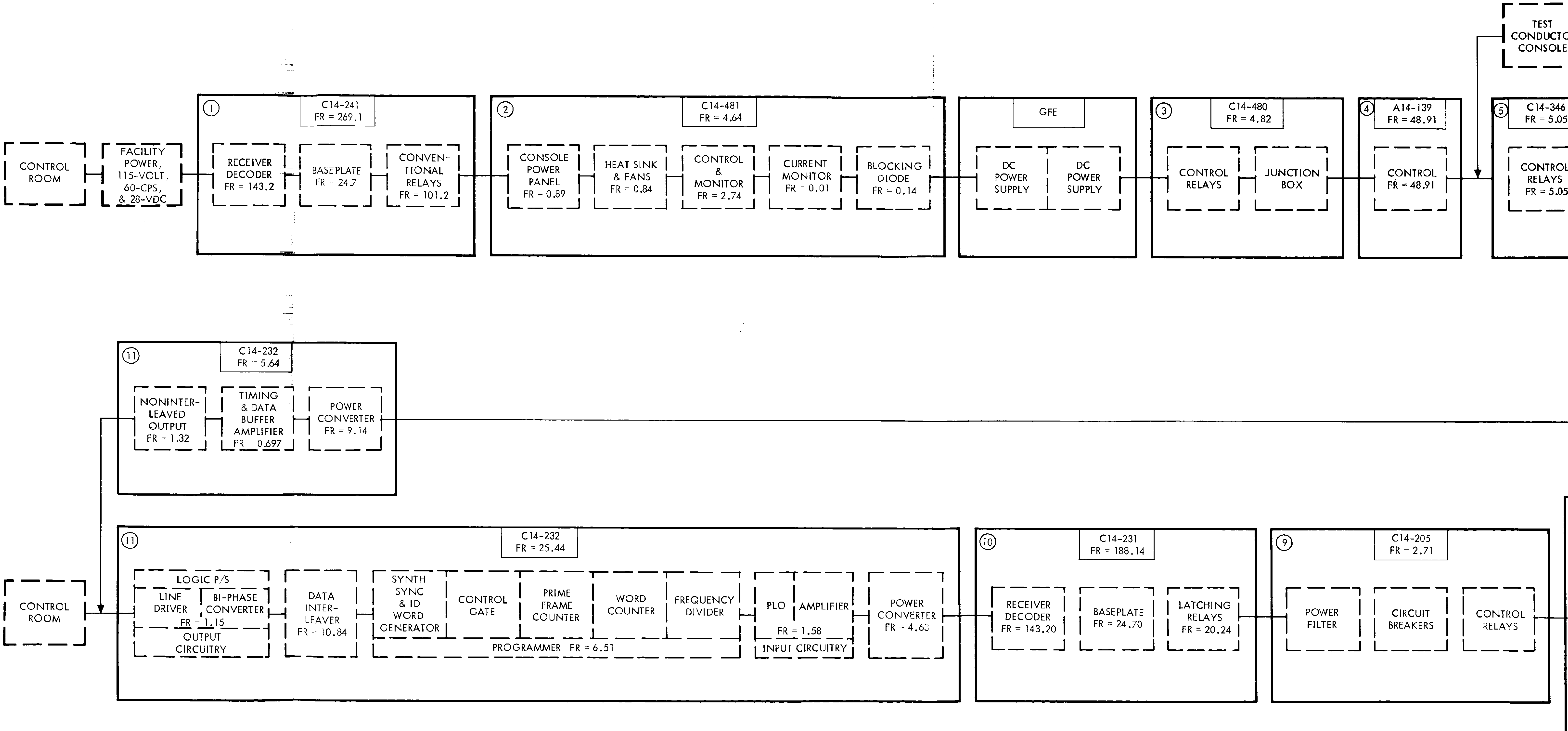


NOTES:

1. TO OBTAIN RELIABILITY OF A–[B, C, D]–E OPERATION WITH 0-PERCENT SYSTEM LOSS = $FR_A + FR_B + FR_C + FR_D + FR_E$
2. REDUNDANT MODE:
3. NOTE 1 PARALLEL PATHS INDICATE INDEPENDENT FUNCTIONS, NOT REDUNDANT PATHS.
4. FAILURE RATE (FR) EXPRESSED IN PERCENT OF FAILURES PER 1000 HOURS.
5. N/A INDICATES NOT AVAILABLE.

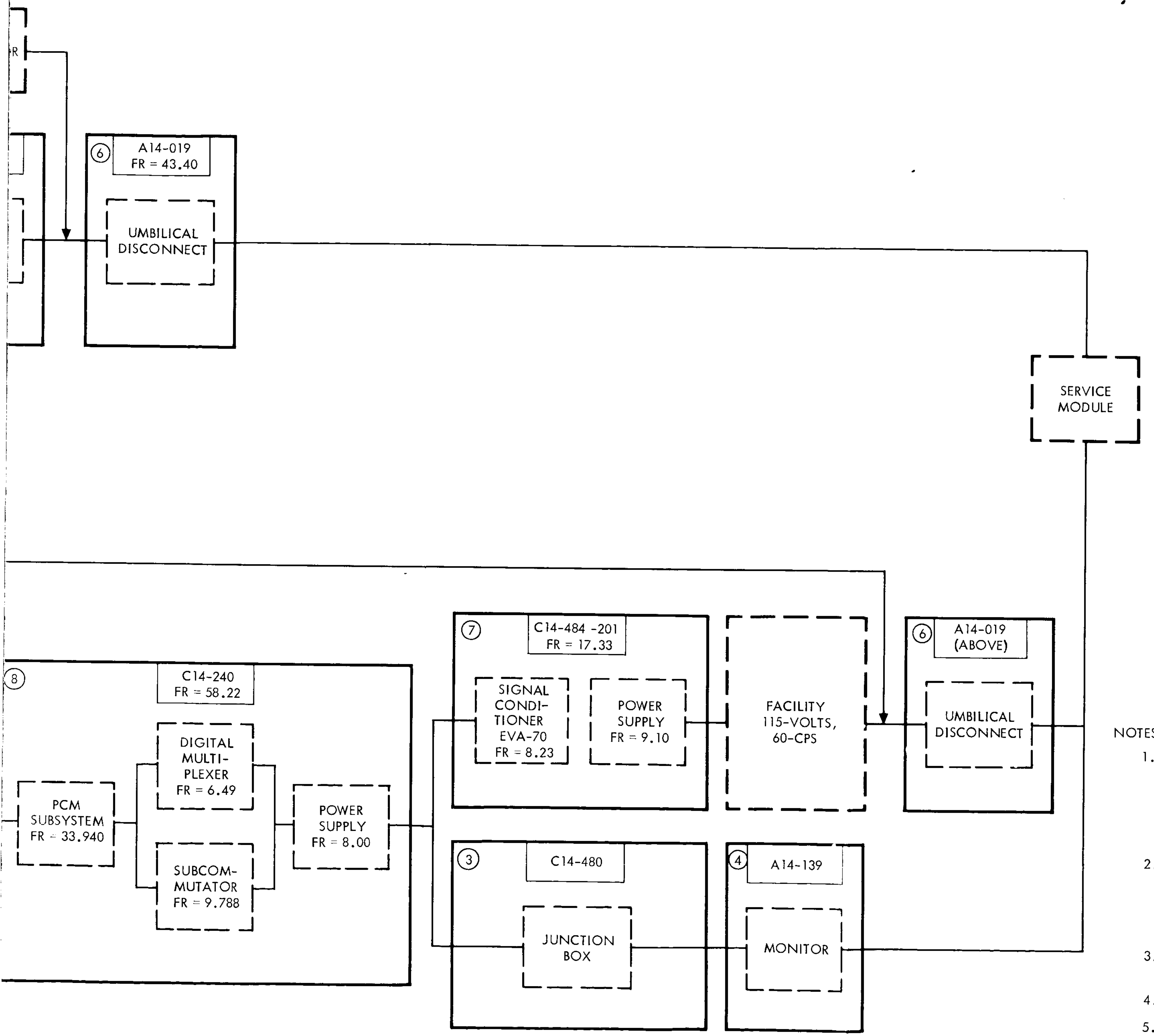
FOLD-OUT #2

Figure 4-4. EPS Spacecraft 009 GSE Functional Logic Block Diagram



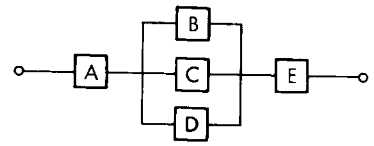
CONTROL ROOM
FACILITY POWER, 115-VOLT, 60-CPS, & 28-VDC
1
C14-241
FR = 269.1
RECEIVER DECODER FR = 143.2
BASEPLATE FR = 24.7
CONVEN-TIONAL RELAYS FR = 101.2
2
C14-481
FR = 4.64
CONSOLE POWER PANEL FR = 0.89
HEAT SINK & FANS FR = 0.84
CONTROL & MONITOR FR = 2.74
CURRENT MONITOR FR = 0.01
BLOCKING DIODE FR = 0.14
GFE
DC POWER SUPPLY
DC POWER SUPPLY
3
C14-480
FR = 4.82
CONTROL RELAYS
JUNCTION BOX
4
A14-139
FR = 48.91
CONTROL FR = 48.91
TEST CONDUCTO CONSOLE
5
C14-346
FR = 5.05
CONTROL RELAYS FR = 5.05
11
C14-232
FR = 5.64
NONINTER-LEAVED OUTPUT FR = 1.32
TIMING & DATA BUFFER AMPLIFIER FR = 0.697
POWER CONVERTER FR = 9.14
CONTROL ROOM
11
C14-232
FR = 25.44
LOGIC P/S
LINE DRIVER
BI-PHASE CONVERTER
FR = 1.15
OUTPUT CIRCUITRY
DATA INTER-LEAVER FR = 10.84
SYNTH SYNC & ID WORD GENERATOR
CONTROL GATE
PRIME FRAME COUNTER
WORD COUNTER
FREQUENCY DIVIDER
PROGRAMMER FR = 6.51
PLO
AMPLIFIER
FR = 1.58
INPUT CIRCUITRY
POWER CONVERTER FR = 4.63
10
C14-231
FR = 188.14
RECEIVER DECODER FR = 143.20
BASEPLATE FR = 24.70
LATCHING RELAYS FR = 20.24
9
C14-205
FR = 2.71
POWER FILTER
CIRCUIT BREAKERS
CONTROL RELAYS

FOLD-OUT #1



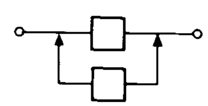
NOTES:

1. TO OBTAIN RELIABILITY OF:



OPERATION WITH 0-PERCENT SYSTEM LOSS = $FR_A + FR_B + FR_C + FR_D + FR_E$

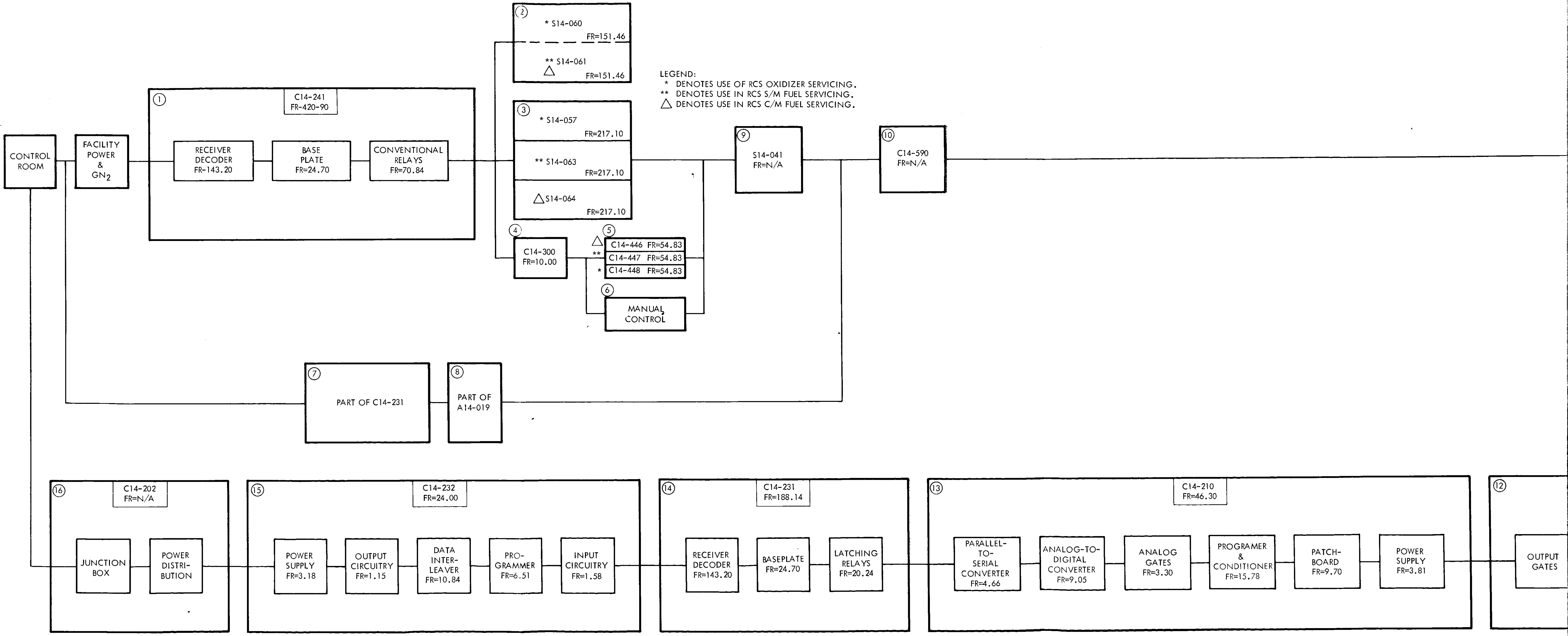
2. REDUNDANT MODE:



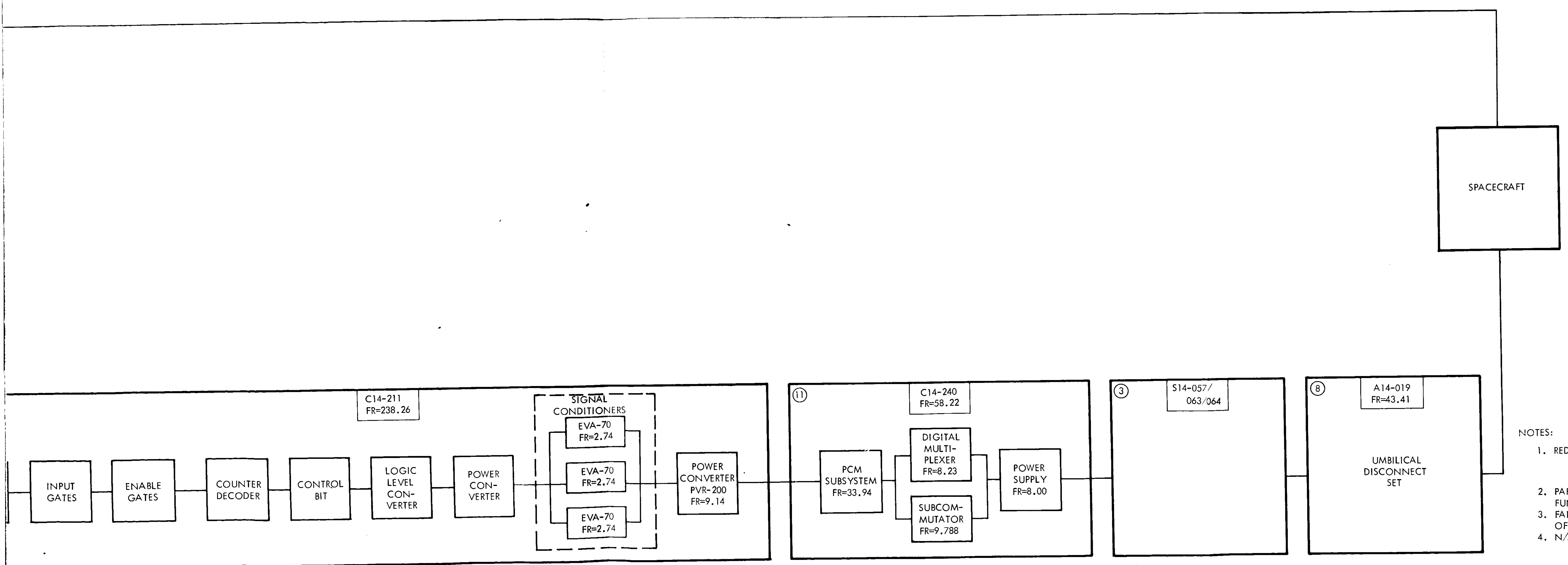
3. NOTE 1 PARALLEL PATHS INDICATE INDEPENDENT FUNCTIONS, NOT REDUNDANT PATHS.
4. FAILURE RATES (FR) EXPRESSED IN PERCENT OF FAILURES PER 1000 HOURS.
5. N/A DENOTES NOT AVAILABLE.

FOLD-OUT #2

Figure 4-5. LES Spacecraft 009 GSE Functional Logic Block Diagram


CONTROL ROOM
FACILITY POWER & GN2
1
C14-241
FR-420-90
RECEIVER DECODER FR-143.20
BASE PLATE FR=24.70
CONVENTIONAL RELAYS FR=70.84
2
* S14-060 FR=151.46
** S14-061 FR=151.46
3
* S14-057 FR=217.10
** S14-063 FR=217.10
S14-064 FR=217.10
4
C14-300 FR=10.00
5
C14-446 FR=54.83
** C14-447 FR=54.83
* C14-448 FR=54.83
6
MANUAL CONTROL
LEGEND:
* DENOTES USE OF RCS OXIDIZER SERVICING.
** DENOTES USE IN RCS S/M FUEL SERVICING.
DENOTES USE IN RCS C/M FUEL SERVICING.
9
S14-041 FR=N/A
10
C14-590 FR=N/A
7
PART OF C14-231
8
PART OF A14-019
16
C14-202 FR=N/A
JUNCTION BOX
POWER DISTRI-BUTION
15
C14-232 FR=24.00
POWER SUPPLY FR=3.18
OUTPUT CIRCUITRY FR=1.15
DATA INTER-LEAVER FR=10.84
PRO-GRAMMER FR=6.51
INPUT CIRCUITRY FR=1.58
14
C14-231 FR=188.14
RECEIVER DECODER FR=143.20
BASEPLATE FR=24.70
LATCHING RELAYS FR=20.24
13
C14-210 FR=46.30
PARALLEL-TO-SERIAL CONVERTER FR=4.66
ANALOG-TO-DIGITAL CONVERTER FR=9.05
ANALOG GATES FR=3.30
PROGRAMER & CONDITIONER FR=15.78
PATCH-BOARD FR=9.70
POWER SUPPLY FR=3.81
12
OUTPUT GATES

FOLD-OUT #1

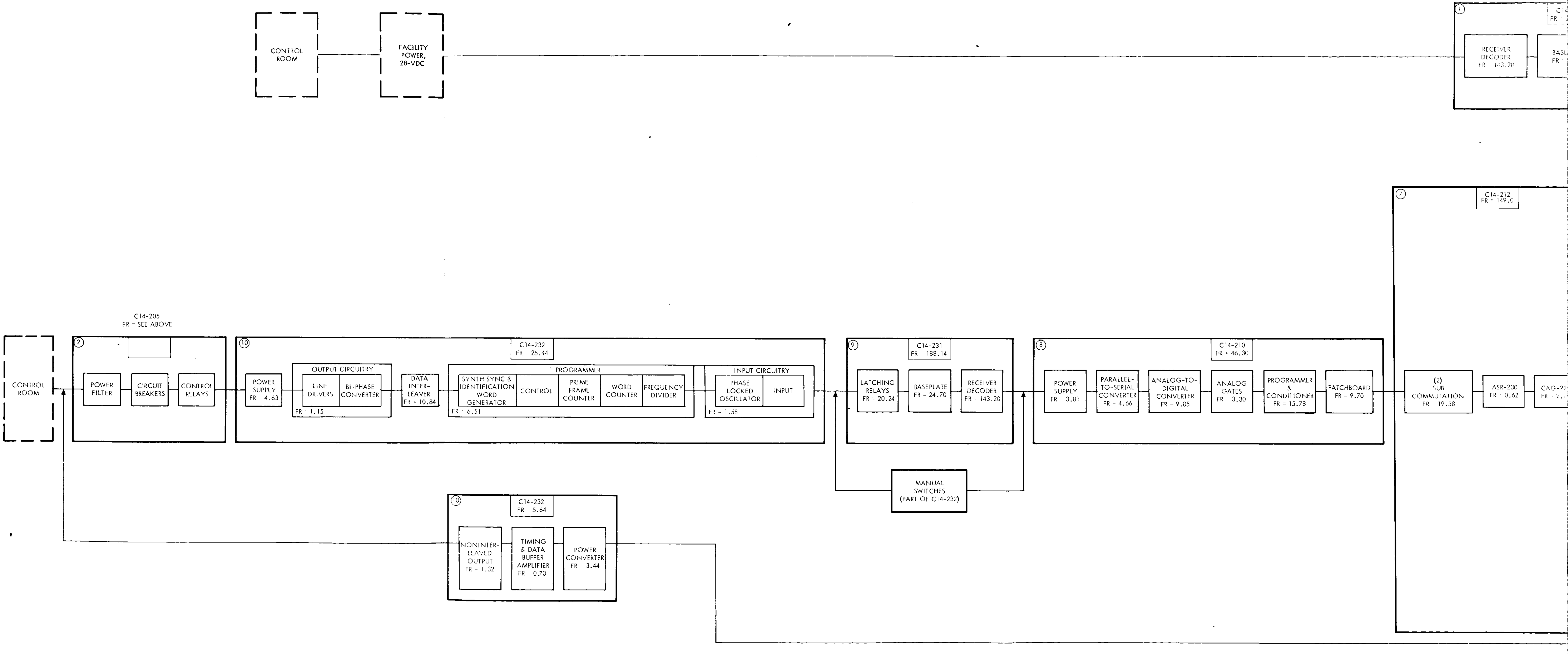


NOTES:

1. REDUNDANT MODE:
2. PARALLEL PATHS INDICATE INDEPENDENT FUNCTION, NOT REDUNDANT PATHS.
3. FAILURE RATES (FR) EXPRESSED IN PERCENT OF FAILURES PER 1000 HOURS.
4. N/A DENOTES NOT AVAILABLE.

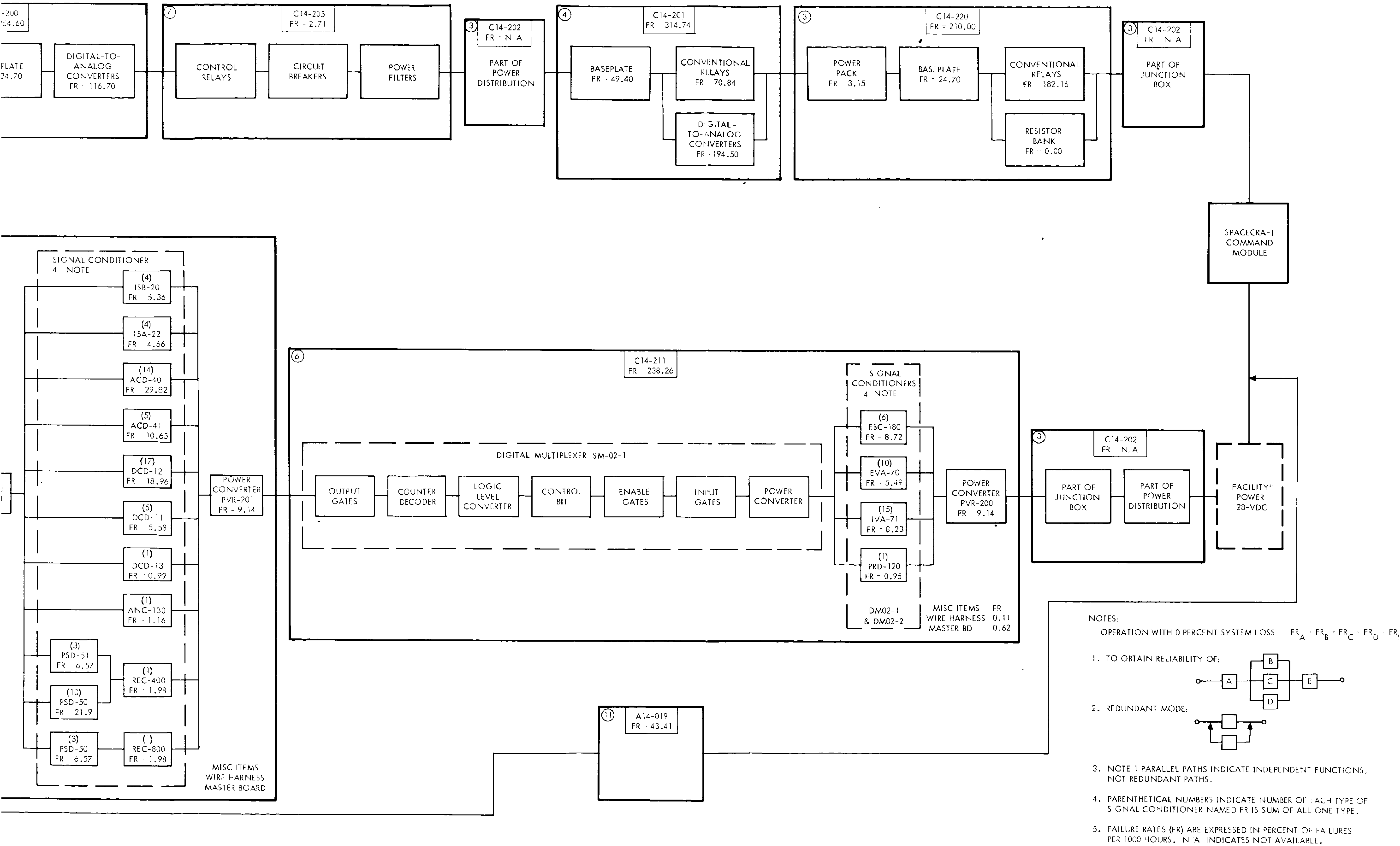
Figure 4-6. RCS Fuel and Oxidizer Servicing, Spacecraft 009 GSE Functional Logic Block Diagram

FOLD-OUT #2



CONTROL ROOM
FACILITY POWER, 28-VDC
1
RECEIVER DECODER FR 143.20
C14-205
FR - SEE ABOVE
CONTROL ROOM
2
POWER FILTER
CIRCUIT BREAKERS
CONTROL RELAYS
10
C14-232
FR 25.44
POWER SUPPLY FR 4.63
OUTPUT CIRCUITRY
LINE DRIVERS
BI-PHASE CONVERTER
FR 1.15
DATA INTER-LEAVER FR 10.84
PROGRAMMER
SYNTH SYNC & IDENTIFICATION WORD GENERATOR
CONTROL
PRIME FRAME COUNTER
WORD COUNTER
FREQUENCY DIVIDER
FR 6.51
INPUT CIRCUITRY
PHASE LOCKED OSCILLATOR
INPUT
FR - 1.58
9
C14-231
FR 188.14
LATCHING RELAYS FR 20.24
BASEPLATE FR = 24.70
RECEIVER DECODER FR 143.20
MANUAL SWITCHES (PART OF C14-232)
8
C14-210
FR 46.30
POWER SUPPLY FR 3.81
PARALLEL-TO-SERIAL CONVERTER FR - 4.66
ANALOG-TO-DIGITAL CONVERTER FR = 9.05
ANALOG GATES FR 3.30
PROGRAMMER & CONDITIONER FR = 15.78
PATCHBOARD FR = 9.70
7
C14-212
FR = 149.0
(2) SUB COMMUTATION FR 19.58
ASR-230 FR 0.62
10
C14-232
FR 5.64
NONINTER-LEAVED OUTPUT FR - 1.32
TIMING & DATA BUFFER AMPLIFIER FR 0.70
POWER CONVERTER FR 3.44

FOLD-OUT #1



FOLD-OUT #2

Figure 4-7. SCS Spacecraft 009 GSE Functional Logic Block Diagram

4.2 SUBCONTRACTOR/SUPPLIER MANAGEMENT

4.2.1 BEECH AIRCRAFT CORPORATION

4.2.1.1 Reliability Program Audit

The comments on deficient areas of the Beech reliability program found by the 3 March audit were answered, and corrective action implementation was assured by Beech.

4.2.1.2 GSS Reliability Schedule

NASA and S&ID conducted a review of BAC GSS reliability efforts on 6 April 1965 at Boulder, Colorado. The review uncovered that BAC's reason for schedule slippage was the high rate of component rejection during component acceptance tests. BAC is to supply a list of approximately 15 of these components and their associated problems to S&ID GSS Design, so that assistance may be given.

4.2.2 NORTHROP-VENTURA

Northrop-Ventura (N-V) notified S&ID that the Fairchild ELS/GSE pressure transducer (N-V No. 58460-1) used in the pressure stimuli generator test set, Model C14-451, could not meet the temperature criteria of +15 to 105 F and the allowable electromagnetic interference (EMI) level specified in the procurement specification. The transducer unit has an operational temperature range from +65 to 85 F that could not be improved without major modifications. Such modifications would result in serious schedule delays.

Reliability conducted an investigation requested by GSS Design to determine the worst environmental conditions to which the Model C14-451 will be subjected during its operation. Because it was established that the GSE model will be operated in a controlled environment with a temperature range from 65 to 75 F ambient, the pressure transducer temperature requirement was changed to a range from 65 to 85 F by GSS Design, with approval of Apollo Reliability.

4.2.3 COSMODYNE CORPORATION

The review of Acceptance Test Procedure CE-461-R, Revision B, was completed. This procedure was submitted by the Cosmodyne Corporation for the LO_2 transfer unit, Model S14-032. The acceptance test, now in process, is being monitored closely because the unit is the first assembled. One failure was encountered in the test for fluid cleanliness in that the particle count was excessive. Fluid flow will be continued until the unit is clean enough to meet the specification requirements.

4.2.4 CONTROL DATA CORPORATION

A reliability audit was performed at Control Data Corporation (CDC), producers of the digital test command system (DTCS) portion of ACE-spacecraft. Required changes to the program were minor and have been effected. Meetings with GSE Engineering, Reliability, Purchasing, and CDC personnel were attended to discuss qualification testing of the DTCS. As a result of the meetings, CDC will use existing acceptance test procedures during qualification testing instead of new procedures and test programming. A significant reduction in qualification time over those originally proposed was accomplished. The procedures submitted were reviewed and approved, and testing is scheduled to begin during June.

4.2.5 ELECTROPLEX

At the Compton Facility, cordwood modules required for ACE Models C14-232 and 240 were found to be discrepant. Analysis indicated that the discrepancies were caused by open welds and component placement. A study performed to determine the ratio of discrepant-to-total modules showed that approximately 4 percent of the modules manufactured before November were discrepant. Modules manufactured after November had a discrepant ratio of approximately 1.5 percent. Modules remaining in stock from November and prior lots were returned to Electroplex for retesting. Of the 500 modules analyzed, six did not pass acceptance testing, and three were mismarked. S&ID Source Inspection has implemented tighter controls to prevent discrepant modules from passing acceptance testing. The supplier's test equipment was redesigned, and the welding schedule reviewed in an attempt to reduce the discrepancy ratio.

4.2.6 MOTOROLA

Motorola's reliability program was found to be acceptable as a result of a reliability audit. Minor changes were requested and have been effected. The Motorola cost proposal for the DTCS was received. Fact finding was performed during May, and negotiations will be completed in June. The Non-Standard Parts List, the I & T Exempt Parts List, and the Reliability Program Plan for the DTCS were reviewed and approved. Motorola is eliminating by redesign the failure modes that can cause the DTCS logic to generate first-order failures.

4.2.7 AiRESEARCH

4.2.7.1 Suit Loop Simuli Generator, ECS/GSE Model A14-033

Reports received from AiResearch and S&ID Engineering indicate that the H_2O metering pump (Part No. 828050-1) which constitutes part of the simulated humidity loop is being installed in two GSE units that will support spacecraft hardware. Because of the past failure history, limited life cycle of 50 hours, and major redesign of the pump, which is to be used on Spacecraft 008, Reliability requested that the pump be subjected to a 14-day off-limit test in a vacuum chamber to simulate the duty cycle of the equipment.

AiResearch has conducted acceptance tests on the ECS/GSE mission-essential models listed in Table 4-1.

4.2.7.2 Reliability Audit

The S&ID reliability audit of AiResearch GSS was held on 8, 9, and 10 March at Torrance. Comments and recommendations for improvement was submitted regarding reliability program management, suppliers' control, design specification control, reliability assessment program, design review program, and failure data acquisition and reporting.

4.2.8 SUPPLIER DOCUMENTATION REVIEW

During the report period, 54 Type I supplier documents were reviewed.

Table 4-1. ECS/GSE Acceptance Test Summary

Model No. and Name	Total Quantity Manufactured	Number Having Passed Acceptance Testing To Date	*Major Problems Encountered During Acceptance Testing*	Remarks
S14-053 Water-glycol trim control set	8	1	Excessive pressure drop due to under-size solenoid valves in the primary loop. EMI incompatibility.	One unit delivered to S&ID in April.
S14-019 Water-glycol service set	8	1	The unit did not reach the designed cooling capability.	One unit delivered to S&ID shipped short with deviations on the cooling capability.
S14-033 Pressure stimuli generator	7	0	Water-glycol pump failures.	Scheduled for delivery to S&ID at the end of April 1965.
S14-034 Pressure dis-tribution set	3	1	Flowmeter for low flow rates will have to be substituted with helium mass spectrometers.	One unit shipped with shortage of five flowmeters

*Problems previously resolved by Reliability

4.3 ANALYSES

4.3.1 ACE-SPACECRAFT POWER FILTERING AND DISTRIBUTION UNIT, MODEL C14-205

A FMEA of the mission-essential Model C14-205 indicated that failure of the 10-volt power supply can cause loss of the airborne PCM data inputs into other ACE-spacecraft equipment. The power supply will be used to furnish the PCM line driver with its 10-volt power in Block II spacecraft. Redesign of the power supply incorporated components of sufficient wattage rating to prevent an over-stressed condition. The components used will be MIL-Standard or better.

4.3.2 SPACECRAFT GROUND POWER SUPPLY, MODEL C14-418

As a result of a FMEA performed on the mission-essential Model C14-418, diodes in a line used to control the motor switch in the spacecraft were changed to prevent occurrence of over-rated conditions during normal operations.

4.3.3 ERRONEOUS DTCS COMMANDS TO SPS

A study conducted as a result of an SPS Design Review indicated that a possible first-order failure mode exists. If the DTCS outputs exceed a +15.2-volt level, the gimbals that align the thrust of the SPS engine through the center of gravity could be damaged. This damage would cause delay in launch operations while the damaged equipment was being replaced. GSS Reliability recommended that a voltage-limiting device be inserted at the inputs to the gimbaling amplifier. This device would limit the voltage to a level that would preclude damage. Engineering is analyzing possible design changes.

4.3.4 PROPULSION SYSTEMS FLUID CHECKOUT UNIT, MODEL C14-075

A FMEA was completed on Model C14-075. As indicated in Table 4-2 of the 470 failure modes analyzed, 14 were first-order. The critical failure modes of the propulsion systems fluid checkout unit, C14-075-201, may be assigned to three general classifications.

Table 4-2. Propulsion Systems Fluid Checkout Unit FMEA

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage	14				5					
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage										
Undetectable failure of a GSE component which results in its replacement or repair		13 14	5			6 7 2 2			1	
Detectable failure of a GSE component which results in its replacement or repair			38 29 35 19 36			33 27 18 29 31	9 2 1 4 2		43 31 21 40	
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance				41 45 28 41 49			1 9 14	44 33 28 41	1	
TOTAL	14	27	162	204	5	155	42	195	170	-
SUM TOTAL	407				397				170	

1. Sensory (pressure gages and flowmeter system). Flowmeter failure could result by acceptance of a faulty regulator. A pressure gage failure of PG-4 for the oxidizer side or PG-5 for the fuel side during leak testing of the SPS relief valve burst diaphragm that resulted in a pressure reading higher than the actual line pressure would cause the leak test to be performed at a lower pressure than that specified. This failure could result in acceptance of a faulty burst diaphragm. AREM/GSS recommends either a redundant pressure indicator or a procedure requiring verification of flowmeter or gage accuracy before each spacecraft system checkout rather than reliance on the mandatory re-calibration period.

2. Contamination. A filter failure and resultant passage of contaminants would be detrimental to mission success. Data are required to verify the capability of the filter to remove all 15-micron largest dimension particles and 98 percent of all 5-micron particles. This failure mode can be reduced to second-order detectable by requiring an examination and sampling procedure with a mandatory signoff by the operator and an inspector before and after each system checkout.

3. Pneumatic Control. Leakage or failure open of MV-2 is a failure mode which would cause GH_e to flow into the GN_2 system, creating a personnel hazard. To preclude this failure, the following precautions are recommended:

    a. A relief valve in the Model C14-075-201 upstream of valve G4MV2, or a check valve downstream of the junction of MV-29 and the GN_2 inlet followed by a relief valve immediately upstream of MV-2.

    b. The test procedure should provide statements at appropriate points warning the operator against the rapid application of high pressure and requiring either a signoff or a statement of verification that the valve is closed.

The basic simplicity of the design and operation of the unit indicates reliable operation can be expected if qualified high reliability components are used and a clear, detailed operational test procedure is published to support training of personnel in the operation of the unit.

4.3.5 POTABLE WATER TRANSFER UNIT, MODEL S14-119

The FMEA on the potable water transfer unit, S14-119 performed by Tulsa Reliability was reviewed and updated to conform with Apollo Reliability's new definitions (see Table 4-3). A flowmeter failure allowing an insufficient amount of water aboard the LEM was the only first-order failure mode revealed. A recommendation was submitted at the 100-percent Design Review of this GSE to double check the amount of water transferred aboard the LEM by weighing the GSE before and after the water transfer function. If this recommendation is adopted, the first-order failure mode will be reduced to third-order detectable.

One second-order (leak must actually exist in spacecraft H_2O system) undetectable failure mode will exist if flow meter FM2 indicates less than the actual amount of leakage. Faulty spacecraft equipment could be accepted, which would ultimately result in crew hazard or mission failure because of insufficient H_2O. This failure mode could be reduced to a noncritical failure mode, if the flow-meter calibration is checked before and after filling.

Table 4-3. Potable Water Transfer Unit FMEA

Failure Mode Order		Serviceability and Launch Status				Total	Failure Effect on Function/Mission (Delay)	
		1	2	3	4		Spacecraft	GSE
I. A single failure or event which may cause loss of personnel	U	1				1		1
	D							
II (a). A single failure or event which may cause loss of mission or countdown delay	U							
	D							
II (b). A combination of any two failures or events which may cause loss of personnel or countdown delay	U	1				1	1	
	D							
III. All others which result in neither loss of personnel nor countdown delay	U			29		29		29
	D							
TOTALS		2		29			1	30
SUM TOTAL		31					31	

U - Cause of failure is undetectable.

D - Cause of failure is detectable.

4.4 QUALIFICATION TEST PROGRAM

4.4.1 QUALIFICATION TEST METHODS SPECIFICATION

Revision A of Specification MA0401-0005 (Apollo GSE Qualification Test Methods) was completed and submitted to the NASA/MSC for approval. This revision corrected minor errors and added rigorous test time controls for the GSE qualification program.

4.4.2 NASA BRIEFING REQUEST

NASA requested S&ID to make a presentation on qualification of GSE by Field Usage at PSDF and WSMR. The briefing was given at a meeting on 29 April 1965 at NASA/MSC, Houston, the facility assigned to evaluate the test results of Spacecraft 001 and F-2 static firing. Support was provided GSE Design Engineering for the program preparation and briefing data.

4.4.3 GSE MODEL QUALIFICATION BY FIELD USAGE

Although several similar GSE models at PSDF and ETR carry the same model numbers and perform similar functions, design and functional mode differences will have to be described in the Qualification Test Report (QTR). Reliability recommended that the exact (as used) differences between PSDF ETR models be defined and presented to NASA for approval before inclusion in the final QTR.

4.4.4 EMC TESTING OF MODEL A14-052

EMC testing of the fuel cell heater power supply was completed. Two discrepancies were found: (1) A meter reading was 20 volts high and required adjustment; (2) A 0.3 db out-of-specification noise level on the input and output power leads during the broad-band conducted interference test was traced to the internal power supply. A similar test was performed on an identical power supply, and the same conditions existed. Engineering, Reliability, Engineering Development Laboratory, and Systems Support personnel concurred that the noise voltage discrepancy of 0.3 db was not large enough to be significant. Although the noise voltage was above the specification requirement, it did not cause malfunction in the Model A14-052 nor nearby equipment.

4.4.5 EMC TESTING OF MODEL A14-126

During EMC testing, the G&N/SCS interface substitute unit (MSE) Model A14-126, experienced failures in three areas: (1) RF interference and susceptibility tests, (2) AF conducted susceptibility tests, and (3) transient conducted susceptibility tests. The unit contains a power supply that furnishes signals for SCS engine ignition, yaw, pitch, and roll. The power supply is susceptible to conducted interference introduced into the +28-volt-power input lead. Additional testing was scheduled in an effort to determine corrective action.

4.4.6 FLUID DISTRIBUTION SUBSYSTEM CONTROL UNIT, MODEL C14-476

Qualification testing of the mission-essential Model C14-476 was completed. Although two nonconformance reports had been issued, it was agreed that retesting of the unit would not be required. The malfunction was due to collection of moisture within the unit caused by the humidity of the air furnished for cooling. When the unit temperature was lowered below freezing, the condensed moisture caused a lamp test switch to freeze in the down position, and also caused low readings on the purge pressure meter. The conditions that caused the failures will not exist under actual operating conditions because GN_2 will be furnished as the purging medium.

4.4.7 ACE CARRY-ON RESPONSE SYSTEM

Representatives of GSE Engineering, the Engineering Development Laboratory, and Apollo Reliability agreed on the qualification test configurations for the ACE carry-on response system. A representative unit will consist of signal conditioners and modules required for Models C14-211, 212, and 213 so that each model can be considered as qualified by similarity.

4.5 FAILURE REPORTING, ANALYSIS, AND CORRECTIVE ACTION

4.5.1 OXIDIZER MOBILE READY STORAGE UNIT, MODEL S14-059

A failure notification report on the mission-essential oxidizer mobile ready storage unit received from WSMR Reliability was Data-fax transmitted to NASA on 23 April 1965. Failure of the Model S14-059 pumping mechanism was detected during a portion of an operational test designed to thermally condition the propellant. The NCR generated about this failure, M83498, recommended a supplier failure-cause analysis on the failed hardware. NCR M53760 of 8 October 1964 reported a similar failure of Model S14-059 pump and requested a Cosmodyne Corporation failure cause analysis. Supplier failure analysis report (SFAR) 2031 was received which stated only that intermittent operation was caused by a faulty chem-pump with internal hot spots created by the pump starter. Apollo Reliability rejected the SFAR because the corrective action taken by the Fosteria Corporation (Cosmodyne's supplier of the chem-pump) does not prevent the repetition of the failure. Apollo Reliability will close out NCR M53760 as soon as a suitable failure report from the supplier is received.

4.5.2 TOXIC VAPOR DISPOSAL UNIT, MODEL S14-060

The final report on the fan blade failure was received on 24 March 1965 from the supplier of the toxic vapor disposal unit, Model S14-060. A failure report and analysis on the fan blade failure compiled by GSS Design Engineering was reviewed by Apollo Reliability. Comments on the report were prepared and submitted to GSS Design for forwarding to NASA. These included:

1. Poor quality control at Joy Manufacturing Co. allowed defective fan blade studs to be placed in service; hence computed design margins could not be used as a basis for reliability confidence.

2. Reinspection of all fan blade studs should be performed after 150 hours of service.

The following recommendations have been made:

1. The appropriate procurement specifications should be revised to incorporate ultrasonic, radiographic, fluoroscopic, and magnetic particle inspections prior to delivery from the manufacturer.

2. Instructions should be incorporated into the Apollo Support Manual to require NAA inspection prior to service and reinspection after 150 hours of service.

4.5.3 RCS VALVE DRIVER AND MONITOR UNIT, MODEL C14-483

Analysis of a nonconformance report on the mission-essential RCS valve driver and monitor unit, Model C14-483, disclosed a malfunction of a switch used to operate the normal and direct coils of the RCS solenoid valves. This malfunction could cause complete loss of the switching capabilities, because the switch is a break-before-make type. The unit was redesigned to use a make-before-break switch, eliminating the possible neutral switch position.

Another nonconformance report on the same model was found to be the result of the excessive heating of a resistor. Corrective action included relocation of the resistor on a heat sink and an increase in the wattage rating of the resistor to prevent stressing above 50 percent of its rated wattage.

4.5.4 FUEL CELL HEATER POWER SUPPLY, MODEL A14-052

Analysis of the failure of the mission-essential fuel cell heater power supply, Model A14-052, revealed that the variable resistors were used in the 28-volt d-c line in such a manner that damage could occur if operation was attempted when the resistors were maladjusted. Corrective action included locating fixed resistors in the current path to prevent damage of the variable resistors from excessive power dissipation. This redesign was effected on all Model A14-052 units.

4.5.5 HEAT SHRINKING

Analysis of failure reports on cable sets indicated that special training of manufacturing personnel would be necessary to preclude the overheating of cable members during heat shrinking of boots and sleeves on cable assemblies. The special training courses were prepared and furnished to the manufacturing personnel and their supervision. In addition, the process specification was reviewed. The training and the revised process specification resulted in a marked improvement.

4.5.6 SPS CHECKOUT AND FIRING CONTROL UNIT, MODEL C14-602

Six power supplies required for the mission-essential SPS checkout and firing control unit, Model C14-602, failed during checkout at WSMR. Thermal tests performed at WSMR indicated a continuous rise in temperature within the power supplies. The power supplies were returned through S&ID to the subcontractor. Tests performed at the supplier's facility showed that two of the power supplies had failed because of shorts within the units and the other four were not defective. It was believed that insufficient cooling at the test site caused the thermal switch within the last four power supplies to actuate. Defective units were reworked, and procedures were initiated at the supplier's facility to prevent recurrence. The cooling problem is being corrected by incorporation of a blower with sufficient capacity to provide proper cooling.